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ERRATA.

- Page 66, line 4, for "*C. farinosa* " read "*Macrura crassifolia* "
- „ 67, line 19, for " no drainage " read " no surface drainage "
- „ 78, line 5, for " 5 years " read " 20 years "
- „ 78, line 6, for " 20 years " read " 5 years "
- „ 130, line 11, and p. 141, line 3, for "*daplidicae* " read "*daplidice* "
- „ 131, line 22, for "*Phaenococcus* " read "*Phenacoccus* "
- „ 134, line 18, and p. 141, line 9, for "*olcaellus* " read "*oleellus* "
- „ 135, line 28, & p. 139, line 4, for "*Aleyodes* " read "*Aleiodes* "
- „ 137, line 8, for "*Phaenococcus* " read "*Phenacoccus* "
- „ 137, line 42, for "*asphondiliae* " read "*asphondyliae* "
- „ 140, line 26, for "*depressiella* " read "*depressella* "
- „ 196, 8 lines from end, for "*C. submorsitans* " read "*G. submorsitans* "
- „ 232, line 31, for "*Argyrotaxa* " read "*Argyrotoxa* "
- „ 232, 3 lines from end, for "*Crysoclista* " read "*Chrysoclista* "
- „ 339, 7 lines from end and p. 342, line 17, for "*Mecosthetus* " read "*Mecostethus* "
- „ 429, line 34, for " D. D. Burt " read " B. D. Burt "

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BULLETIN OF ENTOMOLOGICAL RESEARCH.

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THE INTRODUCTION OF *MEGARHINUS* MOSQUITOS INTO FIJI.

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(PLATE I.)

1. Introductory.

In 1923 the London School of Hygiene and Tropical Medicine sent a research expedition to Samoa to study filariasis, with a view to investigating possibilities for the control of the mosquito *Aedes scutellaris* (*variegatus*), which is the principal carrier of this disease in the South Pacific Islands.

Dr. P. A. Buxton, who carried out these researches in Samoa during 1924 and 1925, made a detailed study of the habits of this mosquito, and in his report (Buxton 1927, p. 121) refers to the question of its control in the following terms :—

“ It is quite impossible in the present state of our knowledge to exterminate this insect, because the great forest areas, with their innumerable little rot-holes, are its stronghold. Any method, therefore, which can be used to reduce the numbers even a little, is valuable. If a predatory insect could be found which would breed in the small cavities beloved of *Aedes variegatus*, an attempt should be made to introduce it. No such insects were found in the New Hebrides, but *Megarhinus* occurs in the Bismarck Archipelago, and further west, and as it is harmless and breeds in holes in trees, an attempt at introduction should certainly be made if opportunity occurs. In this it might be possible to co-operate with the Government of Fiji, which is faced with the control of the same mosquito, and of filariasis.”

This suggestion for the introduction of *Megarhinus*, the larvae of which have long been known to prey on those of other mosquitos, was brought to the notice of the Medical Department in Fiji, where *Aedes scutellaris*, besides being responsible for the dissemination of human, and possibly canine, filariasis, is a distressing nuisance throughout the group, both in town and country districts.

A suitable opportunity for the introduction of *Megarhinus* to Fiji did not arise until 1929, when the writer visited Java in order to collect parasites for the control of a coconut pest in Fiji.

It is not easy to convince a layman that the introduction to his country of a new mosquito, even one which is known to entomologists never to feed on blood, is not fraught with grave risk. Considerable negotiations had, therefore, to be transacted before the project could be attempted, and it was not until 1930 that I received instructions from the Government of Fiji to proceed with the introduction of *Megarhinus*.

The venture had by that time been tried in Hawaii, to which country *M. inornatus* was brought from New Britain in 1929. This project was due to the enterprise of Mr. C. E. Pemberton, entomologist to the Hawaiian Sugar Planters' Association, who studied the habits of *Megarhinus* in New Britain and devised ingenious methods for the collecting, transportation and breeding of it in large numbers. An attempt was made to establish it in Hawaii, on the island of Oahu, with the idea of ultimately distributing it from there to other Pacific Island groups.

After having bred successfully for several generations in the vicinity of Honolulu *Megarhinus* appears gradually to have died out, and a year after its introduction from New Britain Swezey reports that the attempt to establish it in Hawaii was unsuccessful (Swezey 1931).

By the good fortune of a chance meeting with Dr. Harold Lyon of the H.S.P.A. at Buitenzorg in December 1930 I found out that *M. inornatus* had been taken to Hawaii by Pemberton, to whom I wrote for information concerning the details of this project. Mr. Pemberton was good enough to inform me of the methods he had adopted for transporting and breeding these insects, and I should like here to express to him my most grateful thanks for supplying me with much valuable information of which we have made full use in the breeding of *Megarhinus* in Fiji, and without which it would certainly not have been possible to collect such a large colony of this insect for transportation to Fiji in the short time at my disposal before leaving Java.

In January 1931 I set sail from Java to Fiji, where a good colony of *M. splendens* was subsequently landed.

Owing perhaps to the more general occurrence of large trees and forest land, *Megarhinus* found a more suitable home for itself in Fiji than it did in Hawaii, and by the end of 1931 had become established in several parts of the group.

During the course of the work undertaken in connection with the introduction of *Megarhinus splendens* to Fiji some studies have been made of the bionomics of this insect, the substance of which, together with an account of its introduction, form the subject of this paper.

Although a number of references to the breeding-places and the taxonomics of *Megarhinus* are to be found in the publications of the last few years, little has been written about the biology of this most interesting genus since the notes published by Banks in the Philippines (Banks 1906). We think, therefore, that the studies of its habits and biology which we have made in Fiji and Java—though far from exhaustive—are of sufficient interest to justify their publication.

The cost of the project has been trifling, since the expense of the writer's sojourn in Java and passage to Fiji—primarily for other purposes than the collection of *Megarhinus*—were met by the funds of the Coconut Committee in Fiji, and would not have been less had *Megarhinus* not been collected. The necessary apparatus, hire of labour in Java, and distribution of the insect in Fiji, have cost considerably less than a hundred pounds.

Much of the spade-work that enabled this project to be undertaken was done by Dr. P. A. Buxton, to whom not only are my personal thanks due for help at various times, but also the thanks of all in Fiji who may reap the benefit of his suggestion to introduce *Megarhinus* to these islands.

Whilst in Java I received help from Mrs. C. Bonne-Wepster, Dr. S. L. Brug, and others, whom I wish to thank. I should like also to express my gratitude to Dr. S. Leefmans for allowing me to work at the Instituut voor Plantenziekten at Buitenzorg.

The Coconut Committee very generously allowed me to carry out the *Megarhinus* work in conjunction with other duties.

Dr. F. W. Edwards, of the British Museum (Natural History) has determined the specimens of *Megarhinus* which I collected in Java, and later in Fiji, bred from those introduced, and has read through the original text of this paper. I give him my sincere thanks for these and other ways in which he has helped me.

The original text of this paper was written in London during November 1932 ; but as it could not be accepted for publication in this Journal until some twelve months later, I have been able to make a few additions as the result of some further observations in Fiji during the last few months.

At the beginning of 1933 I went to Java, where I remained for three and a half months. In April I returned to Fiji. Calling at Rabaul *en route* I received from the Medical Department there 30 larvae of *M. inornatus*, Walk., which were transported to Suva. Mr. G. Murray, Director of Agriculture in Rabaul, told me that Pemberton, when at Rabaul in 1929, had found the early stages of this species in coconut husks. For this reason it seemed worth while to attempt to get it established in Fiji in addition to *M. splendens* : since split husks of the coconut, which on most plantations in this country are not burnt, form one of the chief breeding-places for *Aedes variegatus*.

Edwards has pointed out (1924) that *M. inornatus* is probably only a local development of the widely spread Oriental form *M. splendens*. It is, therefore, possible that these species may hybridise in Fiji. I have recently received from Suva, where the landed stock of *M. inornatus* was released just three months ago, some sixty larvae of *Megarhinus*, collected from the breeding tubs at Walu Bay. Each larva has been reared through in isolation, since I am unable at present to distinguish *inornatus* and *splendens* in the larval stage, and it is interesting to note that about 10 per cent. of those which have matured are *inornatus*. There is a well marked difference between the two species in the adult stage, there being in *inornatus*, in both sexes, a white ring at the base of the hind tarsi. In *splendens* there is a small patch of palish scales on the dorsal side, at the base of the hind tarsi, but never any complete white ring such as is present on all the specimens of *inornatus* which I have examined. None of the adults bred showed any intermediate condition in the markings of the hind tarsi, and it would appear, therefore, that the two species are probably not intermingling.

The presence, in the material received from Suva, of specimens of *M. inornatus* indicates that this species has bred for three generations in the field at Suva. It will be interesting to watch its progress in other places where *M. splendens* has become established, so that a comparison can be made in the habits and biology of these two closely related forms.

2. The Distribution of *Megarhinus* in Malaya and Australasia.

The mosquito genus *Megarhinus*, of which the larvae of all known species are predacious, is widely distributed throughout the tropics, but was unknown from the Pacific Island groups east of New Britain before 1929.

Seventeen species are listed from the Malay Archipelago and the Australian region ; but toward the south-eastern limit of its range within this area the genus is represented by only two species, viz.—*M. inornatus* from New Guinea, and *M. speciosus* from Australia (Edwards 1932).

Only three species are listed from Java: *M. aurifluus*, Edw., *M. quasiferus*, Leics., and *M. splendens*, Wied. The last named is by far the commonest and is recorded from India, Ceylon, the Malay Archipelago, the Philippine Is. and China (Severn 1926). Besides having a wider geographical range, *M. splendens* breeds in a greater variety of situations than do most other species of *Megarhinus*; it is claimed by some even to be semi-domesticated (Edwards 1924), frequenting the vicinity of human habitations, and it is certainly the dominant and most successful species within the regions with which we are here concerned. At Buitenzorg, in west Java, where all my collecting was done, it was the only species found in any numbers. Buitenzorg is about 800 feet above sea-level and forty miles from the sea. I did not search for *Megarhinus* in many other places, and do not know to what extent *M. splendens* is restricted in its distribution by climatic variations. The material I obtained was all collected in the Botanical Gardens and from a few native villages near by. I did not find *Megarhinus* in the forests; but this may have been due to an inadequate search.

3. The Collection of *Megarhinus* in Java.

Breeding-places.

I began collecting *Megarhinus* at Buitenzorg in July 1930, and collected at intervals during the remainder of the year. I found it first in tree-holes; but as July and August were dry months, only the largest holes contained water. During the last four months of the year, however, heavy rains fell, which considerably increased the number of breeding places.

The following situations were examined in the search for *Megarhinus* :—

- | | | |
|----------------------------------|---|---------------------------|
| i. Large rot-holes in trees. | } | In the Botanical Gardens. |
| ii. Small rot-holes in trees. | | |
| iii. Bamboo stumps. | | |
| iv. Leaf-axils of various Palms. | | |
| v. Bromeliaceae. | | |
| vi. Coconut husks. | | |
| vii. Pitcher-plants. | | |
| viii. Fallen palm spathes. | | |
| ix. Bamboo stumps. | } | In native villages. |
| x. Barrels. | | |
| xi. Tins. | | |

Although repeated searches were made in all these situations *Megarhinus* was found in only the five following :—i, iii, ix and x—every month; ii—only in the wet season. By far the most productive places for collecting were the large holes in the stems and buttress roots of species of *Canarium* in the Botanical Gardens (Plate I, fig. 1). Many of these cavities contain more than two gallons of water, and they provide a perennial reservoir of *Megarhinus*. In such situations *M. splendens* deposits a relatively large number of eggs, and all stages of larvae and pupae are generally to be found.

Repeated collections of *Megarhinus* were made from these large tree-holes, which had a richer fauna in the dry season than after the rains began. Such holes were typical of the trunks of *Canarium decumanum*. No other tree provided so many suitable breeding-places for *Megarhinus*.

Smaller rot-holes are to be found in a great variety of trees, and although they contain water for only a short time—varying from about a day to more than two weeks, depending on the size and position of the hole—many of them provide

sufficient inducement for *Megarhinus* to oviposit. Quite a number of eggs and larvae were collected from these small holes, once the wet season had started, *Aedes albopictus* forming the main supply of food for *Megarhinus* in such situations.

The absence of *M. splendens* from either pitcher-plants or Bromelias seems rather surprising in view of its frequent occurrence in bamboo stumps. In all these three situations there is a permanent but limited supply of water. The water in pitcher-plants is known to be attractive to only certain species of mosquitos; but the water in the centre of certain species of Bromeliaceae, which contains deposits of dead leaves and the larvae of several species of mosquitos, appeared to be a most suitable breeding-place for *M. splendens*, and its absence from that situation seemed rather remarkable.

Large clumps of bamboo grow in almost every native village ("kampong") of west Java. The stems are cut down and put to all manner of uses by the Javanese, and rain-water collects in the terminal node of the cut stump. Although only two or three inches in diameter these holes contain enough water to attract *M. splendens*, which manages to drop its eggs into them. Seldom was more than one individual found in each stump. *Armigeres malayi*, and two species of *Rachionotomyia* were the mosquitos most commonly found in bamboo stumps at Buitenzorg.

Outside almost every kampong dwelling is a barrel containing water with which the natives wash their feet before entering a house. These barrels catch rain-water and falling leaves, and are seldom emptied by the owners. *Megarhinus splendens* breeds in them, feeding on several species of domestic mosquitos, larvae of which are usually present in large numbers.

The number of eggs and larvae of *M. splendens* found in these barrels was never very large, and although there is usually plenty of food in them this particular situation does not seem to attract *Megarhinus* as much as do holes in trees. In several of the colony sites in Fiji, however, where tree-holes are few and far between, large numbers of eggs were deposited in barrels, and more than fifty fourth instar larvae have on occasions been collected in one barrel. It is probable that in Java dragonfly larvae, NOTONECTIDAE and other predators exercise a greater degree of control on the numbers of *Megarhinus* in barrels than they do in tree-holes.

The first collections of *Megarhinus*, during July, August and September of 1930, consisted of larvae and pupae. These were used for experimental purposes, chief of which were series of tests to find out how long larval development could be retarded by reducing the food supply; and also attempts to persuade the emerging adults to mate and lay eggs. Such results of these experiments as are of interest are included in a later section. Not until the beginning of 1931 did I start to collect all the *Megarhinus* that I could find for transportation to Fiji.

Before discovering what its eggs were like, I was unable to collect *Megarhinus* in any great quantity at all rapidly. The larvae and pupae need much searching for. They are shy enough and active enough to make the collecting of them in any number a rather time-consuming occupation, and seldom did a day's collecting produce more than ten individuals. Many of the tree-holes in which a torch revealed the presence of *Megarhinus* were so narrow or tortuous that it was not possible to extract the larvae without special appliances. Other holes, more open, but just as attractive to *Megarhinus*, provided an easy collecting ground.

Collecting.

The first necessity for the collection of the early stages of *Megarhinus* is a powerful electric torch. I used a 5-cell, focussing, Winchester spotlight. A less powerful torch is not nearly so useful, as it does not throw a beam of light beneath the water. For the collection of larvae a "pipette," made of a long piece of glass tubing (about

1.5 cm. diam.) with a strong 3-inch rubber bulb on the end, was found very serviceable. Pupae may easily be damaged if collected in this manner. For them a long-handled, white enamel soup-ladle is a good instrument ; or else they can simply be caught with a fine net.

Owing to their cannibalistic tendencies it is necessary to keep *Megarhinus* larvae in separate containers. All 3rd and 4th instar larvae were kept each in a small glass pot of 1½ in. diameter, and 2½ in. high. A wooden box with a handle, large enough to hold two dozen of these pots, was carried round in the field so that larvae could be isolated immediately as they were collected. The pots were kept about two-thirds filled with water ; tap-water being found quite satisfactory for this purpose.

Pupae were kept together in a large glass jar containing clean water ; except on the occasions when isolation was necessary for individual records. The jar was kept inside an ant-proof cage from which the adults could be removed as they emerged.

The eggs of *M. splendens* are white and almost spherical. They are deposited singly, and float on the surface of the water, where they are blown about by the slightest air currents. The shell is sufficiently tough to protect them from injury when they are dropped : and although we dropped many whilst collecting them in the field we suffered no losses from the chorion becoming damaged.

Provided that it is possible to get one's hand near the surface of the water in a hole where eggs are present, a large water-colour paintbrush is as good an instrument as any to lift them out with, but a steady hand is needed for success in this operation.

Feeding.

During their first instar *Megarhinus* larvae are small and almost transparent, and they require to be fed more frequently than the larger larvae. This is to some extent true for second instar larvae as well. It was found that they seldom survived if starved for longer than three days at this stage of their life. These smaller larvae were kept in specimen tubes of ½ in. diameter, with not more than half an inch of water, and an egg-raft of *Culex* was placed in each tube, so that when the larvae hatched the young *Megarhinus* found an abundant, readily accessible supply of food. If kept in larger pots, such as were used for 3rd and 4th stage larvae, the small *Megarhinus* sometimes died—apparently through failure to find their food.

Larvae of *Aedes argenteus* are more easily caught by *Megarhinus* than those of species of *Culex*, because they usually swim round the bottom of the tubes and generally encounter the *Megarhinus* in so doing ; but as they were not so easy to procure in large numbers I used larvae of *Culex* spp. for feeding *Megarhinus* in the laboratory.

4. The Transportation of *Megarhinus* from Java to Fiji.

From starvation tests carried out with *M. splendens* in Java it was found that although the larvae could live for as long as four weeks without food, and would undergo greatly delayed development when fed with only one *Culex* larva a week, individuals so treated usually produced undersized adults, or else died during the latter part of their pupal instar. But larvae given as much as they could eat during the first two instars, and then kept on a diet of two *Culex* a week for six weeks, matured normally, in spite of a delayed development.

This made it clear that no special difficulty would have to be met for the transportation of *Megarhinus* from Java to Fiji—a journey of only four weeks by direct steamer.

Transport was arranged by a steamer due to sail from Batavia on the 30th of January 1931, bound for Noumea via Port Moresby and Samarai. At Noumea the cargo was to be transhipped to another steamer, diverted there on her way from Sydney to Suva.

As arrangements for utilising this unusually direct route between Java and Fiji were not made until two weeks before the steamer sailed from Batavia very little time was available in which to collect the *Megarhinus* material needed for shipment.

Some fifty of the old stock used for experimental purposes were still in their fourth instar at the beginning of January. Deaths and adult emergences had reduced this number to 36 by the 17th of the month, on which day I started to collect all the *Megarhinus* I could find for shipment. Larvae at that time were very scarce in the larger tree-holes, owing no doubt to the advance of the wet season, which tends to reduce the mosquito population in the larger holes. Eggs, however, were found in fairly large numbers.

On 22nd January 50 eggs were obtained after four hours' collecting. Over 20 were taken from one rot-hole ; and 28 were taken from three holes in another tree.

On the 23rd I had amassed a stock of 311 *Megarhinus*. Of these, 31 were fourth instar survivors from those which had been used for experimental purposes during the previous months ; 69 were eggs ; 96 were in their first and second instars ; 45 were third instar ; and 70 were newly collected fourth instar larvae.

On sailing from Batavia a week later (30th Jan.) a few of these had died and others had yielded adults, so that the shipment on leaving Java consisted of 283 individuals, of which 26 were old stock.

A supply of *Culex fatigans* and *Aedes argenteus* larvae was taken on the steamer and the smaller *Megarhinus* larvae fed when three days out from Java.

During a day spent on shore at Port Moresby (10th Feb.) a large number of *Culex* (probably *sitiens*) larvae were collected from an old canoe lying on the beach. The water in this canoe reacted salt when tested with silver nitrate, although it was not salt to the taste. A *Megarhinus* larva was kept for a day in this water without any ill effects ; after which the entire stock was fed with the *Culex* larvae.

At Noumea it was necessary to wait five days for the other steamer. Here the *Megarhinus* were again fed, this time on larvae of *C. fatigans* collected from old tins in and around the town.

Suva was reached on 27th February ; the voyage from Java having taken exactly four weeks.

The number of healthy *Megarhinus splendens* landed at Suva was 238—45 having died, or emerged as adults, during the voyage. Most of the casualties were from the old stock. As my efforts in Java to breed the adults in captivity had been unsuccessful, those which emerged during the voyage to Fiji were killed as specimens.

5. Colonisation of *Megarhinus splendens* in Fiji.

Organization.

After a complete generation had been bred in Suva from the individuals landed from Java, the Medical Department took over the *Megarhinus* work, the breeding of colonies for liberation being carried out by the staff of the Office of Public Health.

To breed *Megarhinus* in such a manner as to produce a regular supply of pupae in sufficient numbers for liberation is a whole time job for one man ; and from May to August 1931 the Medical Department enlisted the services of Mr. J. C. Flemons, through whose painstaking enthusiasm much progress was made and a rapid output of *Megarhinus* for liberation maintained. Unfortunately lack of funds soon curtailed this progress, and after August the rearing of this insect in Suva was not carried out so expeditiously. But as we were able to reduce the strength of each colony the smaller number of *Megarhinus* bred in Suva during the latter part of the year did not seriously hamper the work of distributing it throughout the group.

Mr. W. C. Cockell, of the Public Health Office, and his Fijian Assistant, Ratu Peni, in addition to their several other duties, did most of the breeding and collection of *Megarhinus* in Suva. The liberation of colonies has been carried out for the most part by Cockell and the writer.

The Breeding of Colonies in Suva.

Attempts were made in Java to breed the adults of *M. splendens* under various artificial conditions; but on no occasion was I successful in persuading females to oviposit, nor do I think that mating ever took place. I was, therefore, especially interested to receive a letter from Mr. C. E. Pemberton about a month before leaving Java, telling me of a method for breeding *Megarhinus* which was successfully adopted with *M. inornatus* in Hawaii, and which it was decided to try in Fiji.

The method consists, briefly, in the liberation of pupae in tubs or large tins in the field. The adults emerge, and, instead of dispersing in all directions, remain near at hand, mate, and finally oviposit in the tubs. This "stay-at-home" habit of *Megarhinus* adults dispenses with the need for keeping them in any sort of cage; and I was informed that in Hawaii, although *M. inornatus* did oviposit when kept in a cage, better results were obtained when pupae were liberated in the manner just described.

We have not tried the cage breeding of *Megarhinus* in Fiji, because we have found the other method so entirely satisfactory.

Our thanks are due to Mr. Pemberton for suggesting the broad principles contained in the following method adopted for the breeding of *Megarhinus* in Fiji. Since the ability to breed a winged insect without confining it in any sort of a cage is a somewhat novel experience I propose to describe the method in detail.

Empty wine or spirit casks were sawn either into two equal half tubs, about two feet in diameter and 20 inches deep, or across one end so as to make one open barrel,* about 20 inches wide at the top and three feet deep. Barrels of this size when half filled with water could accommodate a population of several dozen *Megarhinus* larvae without loss through cannibalism.

A window, about 4 inches wide, was cut out from the side of the tub or barrel (*vide* Plate I, fig. 2), and across the inside of this was nailed a piece of fine-mesh brass wire gauze. This arrangement allows water to overflow after rains without washing out eggs or larvae of *Megarhinus*. The bottom of the window was about 16 inches from the floor in the tubs, and about 20 inches in the barrels. The water-level was maintained at these respective heights.

The site chosen at Walu Bay for the breeding of *Megarhinus* in Suva is sheltered from the prevailing wind by a high cliff; and whilst it contains several large trees (*Inocarpus*), it is only sparingly covered with underbrush, consisting for the most part of *Lantana*. Full sunshine penetrates to most of it.

Eight of the tubs and barrels described above were set out in this locality within a compass of some fifty yards. Some were placed beneath bushes, some beneath trees, and others in more exposed situations. The *Megarhinus* brought from Java were liberated in these tubs and barrels as they pupated, liberations continuing from the 11th March until the 4th April. On the last mentioned date the first eggs to be laid in Fiji were found in one of the tree-holes near by. On the day following, several eggs were laid in one of the barrels.

At the start we collected the eggs from the tubs and barrels as they were laid, and attempted to rear the larvae that hatched in the laboratory, but too much time

* When distinction is required we use the word "tub" to denote a half cask; and the word "barrel" to denote an opened whole cask. Thus a tub is widest at the rim; whereas a barrel is widest half way up.

was taken up in collecting food for the newly hatched larvae, which died if not frequently attended to. So it was found more satisfactory to allow the eggs to hatch in the tubs and collect the larvae after they had reached the third instar. The larvae were then kept in the laboratory in 1-inch specimen tubes, or small glass pots, and given all the food they could eat until they pupated.

Colonies of pupae, as they became ready, were taken out and liberated in other parts of the group; or, as was periodically necessary, were used to replenish the population at the breeding-sites in Suva.

The site chosen at Walu Bay proved to be well suited to the purpose for which it was intended, namely the breeding of *Megarhinus* in large numbers for collection as distinct from its colonisation. Natural breeding-places within the area are few in number, whereas the cliff boundary to the north and east, and the expanse of mangrove swamp to the west provided environs which lacked allurements for *Megarhinus* adults with their feebly developed migratory instincts. Without the provision of artificial breeding-places it is unlikely that *Megarhinus* would survive in such a locality.

TABLE I.
Larvae of Megarhinus splendens collected at Breeding-places in Suva.

Week ending	Walu Bay (5 barrels, 3 tubs)	Draiba (2 barrels)	Lami (1 barrel)	Cakobau Road (2 barrels)	Total
23.v.31 	155	27	—	—	182
30.v.31 	62	61	38	—	161
6.vi.31 	168	7	11	—	186
13.vi.31 	55	52	5	—	112
20.vi.31 	74	8	36	—	118
27.vi.31 	54	47	19	—	120
4.vii.31 	46	22	0	—	68
11.vii.31 	171	16	0	—	187
18.vii.31 	176	14	12	—	202
25.vii.31 	83	16	5	43	147
1.viii.31 	106	5	0	66	177
Av. no. larvae a week from each container	35	12	13	27	—

In addition to those at Walu Bay tubs or barrels were set out in three other places in or near Suva, viz.—Draiba, Cakobau Road and Lami.

Records of the number of larvae collected, and the approximate number of eggs observed when each collection was being made, were kept for each tub or barrel at Walu Bay from 21st May until 4th August 1931, during which period 27 collections of larvae were made. At Draiba 16 collections were made—between 21st May and 31st July. At Lami 10 were made—between 23rd May and 26th July; and at Cakobau Road 9—between 13th and 31st July.

The above table (Table I) shows the number of larvae collected in each site during the weeks ending with the dates given in the left-hand column. The figures

in the right-hand column show that a falling off in the number of larvae collected took place towards the beginning of July. This was occasioned by the death of the original *Megarhinus* adults and consequent cessation of oviposition during the second week of June. It was remedied by further liberations of pupae at these breeding-places.

The original colony of *Megarhinus* with which the tubs and barrels at Walu Bay were stocked consisted of 206 individuals (7 adult, 127 pupae, and 72 fourth-instar larvae). These were liberated between 11th March and 4th April. No further liberations were made for nine weeks. But from the 9th to the 30th June 68 more pupae were liberated at the site; and then a further lot of 37 pupae between the 17th and 22nd July. With this total stock of 311 *Megarhinus* the site at Walu Bay was populated. A collection of larvae at the rate of 100 a week could thereafter, apparently, be maintained if 30 pupae were liberated at the site once a month. This meant that about 330 pupae—allowing for a 10 per cent. loss during breeding—could be made available each month for colony liberation. That number was found to be sufficient for ten colonies.

Unfortunately, owing to economies which necessitated dispensing with the whole-time services of a European for this work, it was not possible to continue such regular collections after August 1931, and although records were made of all the colonies liberated, no further data are available concerning the breeding sites in Suva. But the records made between 21st May and 4th August—in particular that made at Walu Bay—reveal some interesting facts in connection with the habits of *Megarhinus*, of which use was made to improve the methods for breeding this insect.

The tubs and barrels at Walu Bay were arranged as follows :—

- No. I. *Barrel*—beneath *Inocarpus* tree; shaded: no undergrowth near by.
 „ II. *Tub*—beneath a small bush; gets a little sun.
 „ III. *Barrel*—beneath a bush; gets a little sun.
 „ IV. *Tub*—beneath high bushes; gets very little sun.
 „ V. *Barrel*—beneath a tree; shaded: mangrove swamp near by.
 „ VI. *Barrel*—half covered over by a *Lantana* bush; gets some sun in p.m.
 „ VII. *Tub*—in deep shade beneath a thick bush.
 „ VIII. *Barrel*—near to bushes; gets some sun.

At each collection of larvae a note was made of the approximate number of unhatched eggs present in each tub or barrel. The record of eggs noted in the several different containers every fourth day, on fifteen occasions, is as follows :—

			I.	II.	III.	IV.	V.	VI.	VII.	VIII.
None	...	...	1	7	2	7	5	2	10	5
1-5	...	...	6	5	6	4	2	1	3	4
6-20	...	...	4	3	1	2	6	7	2	4
over 20	...	...	4	0	6	2	2	5	0	2

Thus no eggs were present on only one occasion in No. I; on seven occasions in No. II; only twice in No. III,—and so on.

Although the exact number of eggs was not noted the figures given above indicate quite clearly the superiority of the barrels (Nos. I, III, V, VI, VIII) over the tubs (Nos. II, IV, VII) in their ability to attract *Megarhinus* to oviposit, and we found this to be the case in other places. Further evidence of this is given by the numbers of larvae collected from each type of container, as shown in the following figures :—

		Barrels					Tubs		
		I.	III.	V.	VI.	VIII.	II.	IV.	VII.
Total no. larvae collected									
from 21.v. to 4.viii.31	...	194	211	277	230	110	...	87	62 55

The records also indicate that, provided there was free access to its mouth, it did not matter whether the barrel was in deep shade or exposed to the sun for some part of the day. We did, however, notice that when "Ivi" nuts* fell into the barrels and set up fermentation the water became densely populated with *Culex fatigans*, which caused an increase in the numbers of *Megarhinus*.

Thus, a barrel placed in moderate shade, with water containing something attractive as food for mosquitos, and put somewhere where natural breeding-places for *Megarhinus* do not exist, forms the most satisfactory type of container for breeding this mosquito in large numbers.

No less than 92 larvae were collected from a barrel on one occasion; and on as many as thirty-three occasions more than a dozen larvae were collected from one tub or barrel. This shows that provided that an adequate supply of food is available *Megarhinus* larvae are not excessively cannibalistic when living together in a comparatively large volume of water.

It was not necessary to take any special steps for the provision of food for *Megarhinus* in the barrels. The latter became well populated with *Aedes variegatus*, *A. argenteus* (less common), *Culex fatigans* and *C. annulirostris*. There were always more than enough of these mosquitos to meet the food requirements of the *Megarhinus* larvae.

Very few predators attacked *Megarhinus* in the tubs in Suva. But at Waiyevo, on Taveuni, Notonectids and Gerrids found their way into the tubs after a few weeks and greatly reduced the numbers of *Megarhinus*. It is unlikely that such predators will destroy many of the *Megarhinus* which breed in tree-holes.

The Liberation of Colonies up till April 1932.

One would suppose that the best way to liberate a colony of *Megarhinus* in a new country would be to select some locality where natural breeding-places are both plentiful and concentrated within a small area, and then to release one or two larvae in each available breeding place. I had intended adopting some such method on arrival in Suva, at which time seven adults and four pupae required immediate liberation. Actually, when I began to search for such an ideal locality, I realised that in Suva, at any rate, no such place could be found. The eleven individuals just referred to were in the end liberated in a tree-hole on the golf links; but during the ensuing dry season the water in this hole dried up, and the site became useless for *Megarhinus*.

On a few other occasions, in different parts of the group, larvae have been liberated in natural breeding-places, for the most part in holes in the trunks of *Inocarpus edulis*. Most of the colonies, however, consisted of pupae, which were almost invariably liberated in some artificial breeding-place, such as a tin or barrel, placed in some locality rich in natural breeding-places.†

There are several advantages in this procedure. Firstly, pupae do not require to be isolated or fed, and are therefore very easy to transport. Secondly, since the pupal stage is usually only six days, one knows that if pupae are sent out from the distributing centre adults will all be emerging at about the same time, and thus be more likely to mate than they would if they emerged at longer intervals of time. Thirdly, the number of eggs which are laid subsequently in the artificial breeding-place in which the pupae were liberated is a measure of the abundance or scarcity of natural breeding-places in the site chosen, since the emerging adults will lay their eggs in the tin, or whatever may have been used to contain the colony, if natural breeding-sites are not easily found. Much use was made of this fact in our choice

* The fruits of *Inocarpus edulis* (the Tahitian Chestnut).

† By the words "natural" and "artificial" I merely signify distinction between breeding-places already there, and those specially provided in any locality.

of suitable places for breeding *Megarhinus* away from Suva. For this purpose the barrels were put out in localities devoid of natural breeding-places, so that all the eggs were laid in the barrels and a large number of larvae subsequently made available for easy collection.

We had nothing to guide us at first in deciding the minimum adequate strength of a colony. At Walu Bay the first eggs were laid on 1st April, after 88 individuals—mostly pupae—had been liberated at intervals during the preceding 3 weeks. Later on it was ascertained that a week usually elapses between adult emergence and oviposition, which indicated that the liberation of about 50 individuals should be sufficient to produce eggs of a new generation.

After liberating the first twelve colonies, each containing some hundred individuals, we decided that it would be adequate to reduce the strength of each colony to about 30, provided that they were all liberated as pupae. But as opportunities for transport to a desired colony site were not always forthcoming at the moment when material was ready, several colonies had to be made up of such stages as happened to be available when transport offered.

Altogether, fifty-one colonies, comprising a total of nearly 3,000 individuals had been liberated by April 1932, when the writer left Fiji to go on leave, their distribution being as follows:—

Island	No. of colonies liberated					
Viti Levu (S.E.)	33
Vanua Levu (S.E.)	4
Taveuni	4
Rabi	1
Kandavu	2
Ovalau	2
Moturiki	1
Vanuabalavu	2
Lakeba	1

In addition to these fifty colonies liberated in Fiji, the writer took a large colony to Rotuma, an island dependency, situated about 250 miles to the N.N.W. of Vanua Levu. Here a good site for a colony was found. *Aedes variegatus* is abundant on the island, and filariasis is rife.

The more important parts of Fiji have now received colonies of *Megarhinus*; but there are yet many islands, where conditions are suitable for its establishment, which have yet to be stocked. Most of these lie in the south-eastern part of the group, and are isolated and often difficult of access, so that it will probably be several years before *Megarhinus* has become established all over the group.

The north-western parts of the two largest islands (Viti Levu and Vanua Levu) are comparatively dry and only sparingly covered with forest belts. We have made no liberations of *Megarhinus* in these districts hitherto, and it is improbable that the insect will ever colonise in these parts of Fiji.* But in the central parts of these two large islands clumps of bamboo are scattered throughout rain-forest zones, offering scope for the establishment of *Megarhinus*.

It is to be hoped, now that *Megarhinus* has become established in several places, that local enthusiasts may undertake its further distribution whenever suitable opportunities arise. Much can obviously be done in this way to accelerate its

* I was informed on returning to Fiji this year that an attempt had been made to get *Megarhinus* established at Lautoka—a town on the western side of Viti Levu, with an annual rainfall little more than half that of Suva. Two hundred were liberated; but none have been recovered or seen since. It would seem to me to be very unlikely that the insect will ever spread into this dry-zone territory.

colonisation throughout the group, which would take place extremely slowly if the insect were left to spread of its own accord from those places where it is now established.

Recoveries of Megarhinus.

Of the 51 colonies liberated in Fiji and Rotuma, 35 were put out in sites which have not yet been revisited. Of the remaining 16, five have been revisited without the discovery of *Megarhinus*, and in six more the insect has been recovered and is apparently well established. The other five colonies were liberated, in Suva and elsewhere, expressly to form breeding centres; in two of these, however, *Megarhinus* has subsequently been recovered in natural breeding-places.

In Fiji only one type of country offers ideal conditions for the permanent establishment of *Megarhinus*. This is afforded by the groves of the Tahitian Chestnut tree (*Inocarpus edulis*)—the “ivi” of the Fijians. These trees have fluted trunks and large aerial buttress roots, amongst which there is usually a number of water-holding cavities. This tree grows in greatest profusion in the swamps which occur near the shore, where a fresh-water stream is dammed back by a tidal beach of coral sand (Plate I, fig. 3). The ground in such swamps is usually muddy, and no undergrowth impedes the flight of *Megarhinus* from tree to tree.

Three out of the four colonies known to have become established on the islands Viti Levu, Vanua Levu, Taveuni and Ovalau were liberated in these swamps.

6. The Probable Value of *Megarhinus* in Fiji.

Megarhinus splendens was landed at Suva on the 27th February 1931. By the beginning of August of that year fourteen colonies had been liberated, at the sites of six of which the insect was recovered later in the year. By April 1932 it had bred for nine months (*i.e.* through nine generations) in natural breeding-places in at least one colony site, where it is still abundant (August 1933); so that it is now certain that the mosquito has become established in this country.

This contrasts with the apparent inability of *M. inornatus* to colonise in Hawaii; and gives more grounds for hope concerning the value of *Megarhinus* in the island groups of the south-western Pacific than were held out by the results of the initial venture to establish it in Hawaii.

At so early a stage in the colonisation of *M. splendens* in Fiji it is, perhaps, rather idle to propound any theory as to the benefits which may follow on its introduction. But it is worth while to review certain of its habits, which may have a bearing on the ultimate position which it will occupy as a member of the mosquito fauna of Fiji.

A brief, but thorough survey was made of all the water-containing tree-holes within six feet of the ground at one colony site three months after *Megarhinus* had become established, and from the data obtained during this survey, which are set out in the concluding part of this section, one can form some opinion of what *Megarhinus* may be expected to do in at any rate one type of locality in Fiji.

The following factors concerning the biology and habits of *M. splendens* militate against its effectiveness as a control for *Aedes variegatus* :—

- a. Lengthy development—at least 24 days from egg to adult.
- b. Does not usually lay its eggs in coconut husks or small tins.
- c. Is apparently unable to spread where undergrowth is at all thick.
- d. Its abundance is largely affected by rainfall.

For a consideration of these factors it may be pointed out that the first three are all closely inter-related. A long immature period is an embarrassment in so far as it entails risk of destruction through the complete evaporation of the water

in a breeding-place of small water-holding capacity; moreover its eggs cannot withstand desiccation and are very frequently splashed out by rain. This quite possibly is the reason why *Megarhinus* seldom lays in coconut husks and certain other of the less capacious breeding resorts of *A. variegatus*. But an increased rainfall offsets this difficulty to some extent, although it will be shown that there are grounds for believing that *Megarhinus* will exercise a more efficient check on *Aedes* in the dry than in the wet season.

The survey of tree-holes, mentioned above, was made at Waiyevo, on the west coast of the island Taveuni, where there is a narrow strip of swampy ground extending for about half a mile, parallel with and within a hundred yards of the shore. This swamp is interrupted in the centre by a ridge of high ground (fig. 1) about 150 yards in width, which has a few large trees growing on it but no dense undergrowth of bushes. Another break in the swamp occurs to the south of the ridge. This is some 200 yards wide, and here the undergrowth is fairly thick. There are thus three separate swamps, indicated on the accompanying sketch map (fig. 1) by the areas marked I, II and III—enclosed by dotted lines.

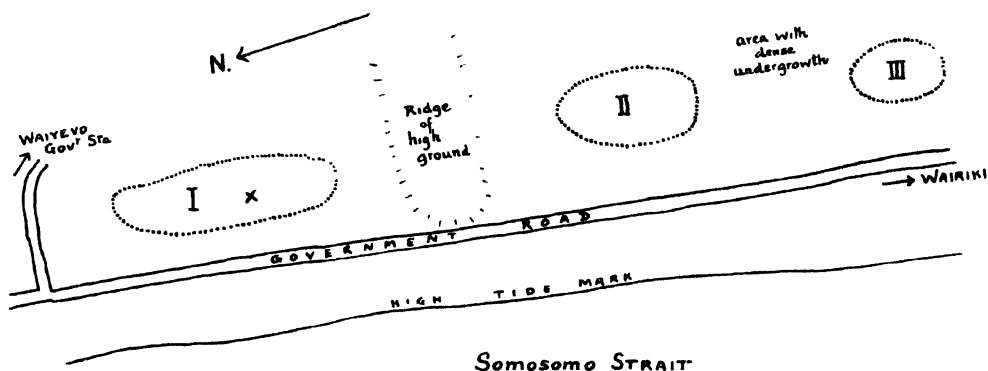


Fig. 1. Sketch-map showing the position of three swamps with *Inocarpus edulis* (marked I-III, with dotted outline), at Waiyevo on the island of Taveuni, Fiji. The length of coastline shown is about 1,000 yards. The scale is only approximate. A colony of *Megarhinus splendens* was liberated at the point marked X in swamp I on 10.viii.31.

Megarhinus was liberated in July 1931 at the point marked x in I (Plate I, figs. 2, 3). By the end of September it had spread right through this bit of swamp, but at that time no examination had been made of II and III. On 14th October a search was made in all three swamps. *Megarhinus* was abundant all through I (for details see p. 18); two larvae and a few eggs were found in II, although a large number of tree-holes were without *Megarhinus*; none, however, were found in III. Larvae were also found in a few trees 80 yards from the northern end of Swamp I.

In January 1932, by which time nine generations must have bred in this area, another search was made, and *Megarhinus* had still not found its way into III.*

In each of these swamps at least six tree-holes held water all through the dry season. It would appear then, that within the boundaries of I, which like most swamps of *Inocarpus* is singularly devoid of undergrowth, *Megarhinus* spread at the rate of about 100 yards a month. But its failure to reach III in six months, after having reached II in three, suggests that its progress to the south was barred by the stretch of rather dense undergrowth intervening between these two areas of swamp land.

* This locality was revisited in July 1933. Swamp III no longer offered attractions as a breeding-place for *Megarhinus*, the trees having been felled for fire-wood. In the other swamp areas *Megarhinus* was still abundant.

In confirmation of this supposed inability to penetrate undergrowth, we have noticed that, at the margins of the swamps, trees surrounded by leafy bushes or boughs are seldom reached by *Megarhinus*.

It was expected that the colony liberated at Lami, some five miles from Suva, at the end of April 1931, would spread up into the forest on the slopes of the hill Korobaba, at the foot of which it was liberated. A large accumulation of water was found in the base of an old hollow tree-stump half-way up the hill (*i.e.* about 600 feet above sea-level). Several times we inspected this ideal breeding-place, which contained *Rachionotomyia purpurata* in large numbers as well as a few *A. variegatus*; but *Megarhinus* had not reached it by April 1932. Typical wet-zone mountain forest extends from the colony-site at Lami right up to this tree-hole, over a distance which, measured in a straight line, cannot be more than $\frac{3}{4}$ mile.

Judging from this instance of failure to spread it cannot be expected that the dispersal of *Megarhinus* through forest areas is going to take place very rapidly, although it is necessary to point out that in the forests of Viti Levu, unlike that on Taveuni, natural breeding-places for *Megarhinus* are of rather limited occurrence.

Having now reviewed what appear to be the more important limitations imposed on the efficacy of *Megarhinus* as a control for *Aedes*, let us turn to the more hopeful side of the question and see in what respects *Megarhinus* promises to be of use.

- a. It is not particular regarding its food.
- b. Its development is not abnormally retarded by the climate of Fiji.
- c. It does not object to breeding close to houses.
- d. It has probably few natural enemies in Fiji.

With regard to its food, I have not yet come across any species of mosquito larva which is distasteful to *Megarhinus*, and I have tried it with very many different species. But besides eating mosquito larvae it has been seen in the field feeding on a species of *Chironomus*, and in Java a fourth instar *M. splendens* was seen with its mandibles inserted into the carcase of a large Tipulid larva, of which all that remained was the abdomen. In captivity I fed larvae on small tadpoles, and saw one feeding on a caterpillar of a Pyralid moth which I was breeding, and which had accidentally fallen into the tube with the *Megarhinus*; moreover, Pemberton told me that he fed *M. inornatus* during the journey to Hawaii on termites. In fact *Megarhinus* makes a grab at anything which may disturb the water near where it is lying, as can easily be seen by gently stirring the water near a larva with a needle and watching the larva make a snap in the direction of the movements. *Megarhinus* does not feed in any other manner than as a predator, but its ability to feed on such a variety of living things must help it to survive in places where *Aedes* is not always obtainable.

And now as regards temperature. It has been found with several of the insects which have been brought to Fiji from Java during the last few years that a very considerable lengthening of the development has occurred as a result of the lower temperature in which they have had to live in their new home. I made tests in Java, and later in Fiji, to determine the most rapid development of *Megarhinus*, and found a difference of only two days in the larval period between Java and Fiji, whilst no difference was noted in either the incubation or pupal period. Furthermore, the tests in Fiji were made during August, which is one of the coolest months of the year. This suggests that the number of generations per annum in Fiji will probably be only one less than it is in Java.

It has been stated by many writers that the species of the genus *Megarhinus* are sylvan in habitat. Whatever may have been its original home it is hard to believe that *M. splendens* is now wholly, or even mainly, forest-frequenting. In Java it was of common occurrence in tubs at the doors of native houses. In the

Philippines, Banks obtained specimens from the top of a bamboo ladder leading to the door of a native house ; and recently Brug took it on the coastal plains of Java in the leaf-axils of such a frequently cultivated plant as *Colocasia indica* (Brug 1931). These records all suggest that *M. splendens* is a very plastic species, which may be able to find a home for itself in quite domestic surroundings in places where tree-holes and bamboo stumps—given by most observers as the usual breeding-places for this species—are not available.

Senior-White, in Ceylon, found *M. splendens* in association with the tree-hole and bamboo breeding group of mosquitos. He says about it—"Though it will, exceptionally, tolerate high alkalinity, it will apparently not suffer any great amount of acidity ; whilst it requires solutions of a rather restricted, though high, range of concentration " (Senior-White 1926). He collected *M. splendens* from water, the pH value of which ranged from 6.6 to 8.8. I have neither made nor seen any readings for the average pH value for the water contained in the leaf-axils of " taro " (*Colocasia esculenta*), but would imagine such water to be alkaline. Brug's record of *M. splendens* in leaf-axils of *C. indica* (the " via " of the Fijians) is of great interest and importance, since it suggests the possibility of a similar habitat being utilised in Fiji.

Taro (or " dalo ") is the staple food of the Fijians and is cultivated extensively. Therefore, should *Megarhinus* breed in taro-axils in Fiji, it will become much more abundant and generally distributed than can ever be the case if it breeds solely in tree-holes, bamboo and tins. In spite of the small volume of fluid which leaf-axils of *Colocasia* can hold, it is only after several weeks of rainless weather that they become dry. There is no reason, therefore, why this situation should not be used by *Megarhinus*, so far as the risk from evaporation is concerned. The only mosquito known to breed in *C. esculenta* in Fiji is the non-biting species *Uranotaenia colocasiae*. This mosquito is widely distributed on certain islands, and, although being itself predacious to some extent, would provide an ample supply of food for *Megarhinus* breeding in this situation. In axils of *C. indica* mosquito larvae are not so commonly met with—*U. colocasiae* being the most usual species—although on one occasion *A. variegatus* was found by the writer in this situation. There is certainly a difference in the taste and appearance of water from the leaf-axils of *C. indica* (" via ") and *C. esculenta* (" dalo " or " taro "). This is probably in the main due to the fact that more rain-water finds its way into the axils of *indica* than into those of *esculenta* (Buxton, p. 97) ; so that sap-like exudations from the plant, which accumulate in the latter, are constantly being washed out in the former.

Whilst the form of the breeding site in these two plants is sufficiently similar to suggest the possibility that *Megarhinus* might oviposit in both species, I feel certain that neither of them had been used by *M. splendens* at the end of its first year in Fiji. It remains to be seen whether it will take to these plants in the future.*

Tree-holes, sufficiently voluminous to contain water for at least three weeks after rain, are not of very frequent occurrence in most of the forests in Fiji, and it is an open question whether the insect will find enough breeding-places to enable it to colonise in forest areas. Bamboo grows plentifully over much of the wet-zone area in Viti Levu and Vanua Levu and should provide an abundance of breeding-places for *Megarhinus*.

In Fijian villages barrels, such as are to be seen in almost every " kampong " in west Java, are not much used. But a wooden gong (" lali "), made out of a hollowed-out log, is the possession of almost every native settlement ; and in these *Megarhinus* is almost sure to breed.

* Since writing the above I have recently (July 1933) found *M. splendens* in leaf-axils of *C. esculenta* (" taro ") at Waiyevo, Taveuni.

TABLE II.

Records of Megarhinus splendens and Aedes scutellaris (variegatus) in tree-holes of Inocarpus edulis at Waiyevo, Tavuni, October 1931.

Tree no.	Holes with water	Approx. water content in cu. in.	<i>Megarhinus splendens</i>	<i>Aedes scutellaris</i>	Notes
I	1	3	+	0	
II	0				
III	1 2 3	8 1 $\frac{1}{2}$	++ ++ +	+ 0 +	Large hole nearly dry Very small
IV-VII	0				
VIII	1	> 50	+	+	
IX	1 2 3	> 50 20 < 4	+ 0 0	0 + 0	A narrow crack
X	1 2 3	4 4 $\frac{1}{2}$	++ ++ 0	++ ++ 0	Almost blocked by foliage Muddy water
XI	1 2 3 4	10 2 2 1	+ 0 + 0	+ + 0 +	No room for <i>M.</i> to oviposit
XII	1 2	6 3	++ +	0 0	
XIII	1 2 3 4 5 6 7 8	> 100 > 100 30 15 8 6 4 1 $\frac{1}{2}$	0 + + 0 + + + +	0 0 0 + 0 0 0 +	Difficult to examine
XIV	1 2 3 4 5 6 7 8 9 10 11 12 13	100 80 50 20 12 10 6 4 4 2 1 $\frac{1}{2}$?	++ ++ + 0 0 + + 0 0 + + 0 0	0 0 0 0 0 0 0 + 0 + 0 0 0	Tunnel in buttress root Very narrow aperture to hole Very narrow aperture to hole Tiny crack very inaccessible
XV	0				
XVI	1 2	20 10	+ 0	+ +	
XVII, XVIII	0				

TABLE II.—*continued.*

Tree no.	Holes with water	Approx. water content in cu. in.	<i>Megarhinus splendens</i>	<i>Aedes scutellaris</i>	Notes
XIX	1	20	+	0	
XX-XXII	0				
XXIII	1	12	0	0	
	2	4	0	+	
XXIV	1	10	0	+	
	2	10	+	0	
	3	3	0	+	
XXV	1	50	+	0	
	2	4	+	0	
XXVI	0				
XXVII	1	12	+	+	
	2	0	+	+	Larvae found by adding water to wet mud
XXVIII-XXXI	0				
XXXII	1	10	0	0	
	2	2	0	+	
	3	1	+	0	Very small hole
XXXIII	1	200	+	0	Very deep
XXXIV	1	> 100	+	0	Very deep
	2	40	0	+	
	3	10	0	+	
	4	4	0	0	
XXXV-XXXVI	0				
XXXVII	1	50	+	0	
	2	50	0	+	
	3	18	0	0	
	4	4	0	+	
	5	2	+	0	Nearly dry
	6	1	0	0	Nearly dry

+ present.

0 not present.

In coconut plantations, mangrove swamps and over large tracts of country in the drier parts of the group there would seem to be little chance of *Megarhinus* being able to colonise permanently and play much part in the destruction of *Aedes*. There is, however, one situation in Fiji, to which I have made reference above, which seems to be extremely suitable for *Megarhinus*: this is afforded by the swamps and groves of *Inocarpus edulis*.

The spread of *M. splendens* through the swamps at Waiyevo has already been discussed (p. 14). The following data, derived from a survey of all tree-holes less than six feet from the ground in Swamp I at Waiyevo, are of interest.

A *Megarhinus* colony, comprising about a hundred individuals—larvae, pupae and adults—was liberated in two tubs at the centre of this swamp on 10th August 1931.

Eggs were found in tree-holes near by two weeks later, and the survey was made from 13th to 15th October 1931, *i.e.* after two generations had bred in natural breeding-places in this locality. Every tree was examined carefully for water-containing cavities and the latter were inspected with an electric torch to see whether *Megarhinus* or *Aedes* were present, no account being taken of other species of mosquitos. An approximate estimate of the volume of water in each tree-hole was made. Altogether, 37 trees were examined, 18 of which contained holes with water. The total number of water-containing holes examined was 64, the greatest number in one tree being no less than 13.

In Table II a list is given of all the data obtained from this survey. From these figures it will be seen that :—*Megarhinus* and *Aedes* were present together in 11 holes ; *Megarhinus* was present and *Aedes* not present in 25 holes ; *Megarhinus* was not present, but *Aedes* present in 15 holes ; and neither species was present in 13 holes. *Megarhinus* was thus present in 36 out of 64 holes, or slightly more than 50 per cent. ; whereas *Aedes* was present in only 26 holes, or about 40 per cent.

It is interesting to examine these figures with a view to ascertaining the mathematical significance of the difference between the percentage of holes containing *Aedes* in which *Megarhinus* was, and was not present. Thus in 11 out of 26 holes (30·56 per cent.) in which *Megarhinus* was present, *Aedes* was also present ; whereas in 15 out of 28 holes (53·57 per cent.) in which *Megarhinus* was not present, *Aedes* was present. The standard error of the difference in these percentages works out at 12·39 ; and the ratio of the percentage difference (23·01) to its S.E. is thus $\frac{23\cdot01}{12\cdot39}$ or 1·86. The probability is, therefore, 0·06. In other words there is only a chance of 1 in 16 that the lower percentage of holes with *Aedes* when *Megarhinus* was present, than when it was not present, was due to coincidence.*

Of the holes in which I estimated the volume of water to exceed 20 cu. in. *Megarhinus* was found in 13 out of 18 (72 per cent.) ; whereas in holes with less than this amount of water, it was found in only 23 out of 46 (50 per cent.). I have made this quite arbitrary distinction between large and small holes because I think that the holes with more than 20 cu. in. of water would be unlikely to become dry in less than three weeks of rainless weather ; or, in other words, that in such holes there is little risk that *Megarhinus* will be killed by the water drying up.

The figures for rainfall at Waiyevo from July 1931 until January 1932, together with the average for those months, are as follows :

				1931-32.	Average rainfall.
July	...	...	...	1·03	2·37
August	...	...	...	12·26	4·10
September	...	...	...	3·78	4·80
October	...	...	...	1·21	7·40
November	...	...	...	1·81	8·97
December	...	...	...	6·27	10·45
January	...	...	...	25·32	10·94

There were three consecutive weeks without rain in July, and another two weeks without rain from 18th August until 3rd September. *Megarhinus* not only survived the July dry period, but was sufficiently abundant at the end of the month to utilise the greatly increased number of breeding-places which resulted from the heavy falls of rain in the early part of August. From the 19th August till the 13th October the

* Dr. J. O. Irwin of the London School of Hygiene & Tropical Medicine was kind enough to work out these figures for me.

rainfall was a great deal less than the average for that period of the year, so that the survey of breeding-places which was made may be said to be representative of the conditions which obtain in the very driest period of an average year.

It was unfortunately not possible to carry out another complete survey after the heavy rains which fell early in 1932; but on 30th January I revisited the swamp for the collection of *Megarhinus* and made the following entry in my notebook: "Very heavy rains all the last few days and almost every tree-cavity filled. Out of those examined it is estimated that not more than 20 per cent. of those which contain mosquito larvae contained some stage of *Megarhinus*. The filling up of many holes which only contain water after the heaviest rains provides *Aedes variegatus* with many breeding-places which are virtually useless for *Megarhinus* owing to the rapidity with which they become dry.

It was quite evident at the time this second examination was made that the proportion of tree-holes in which *Aedes* was present had greatly increased as a result of the advent of the wet season. It would, therefore, seem probable that, in an area of country such as that which we have been considering, *Megarhinus* will exercise a greater degree of control on *Aedes* in the dry than in the wet season.

Buxton (l.c., p. 106) lists the following breeding places of *A. variegatus* in Samoa:—

1. Coconut husks and shells.
2. Tins, mostly small.
3. Rot-holes in trees.
4. Wells in palms.
5. Holes in lava.
6. Hollow top of coconut stump.
7. Barrels and tanks.
8. Open concrete drain.
9. Cacao pods.
10. Crab-holes.
11. Village gongs.
12. Cut bamboo stumps.
13. Jug of clean water.
14. Hollows among roots.

In Fiji this mosquito has been found in situations either identical or strictly comparable with all of these, with the exception of crab-holes and cacao pods. I have not yet examined crab-holes for mosquito larvae in Fiji, and have found no reference to such places as breeding mosquito larvae in this country; but I feel certain that they must be used by *A. variegatus*.* Cacao is no longer grown. In addition to this fairly considerable list of breeding-places *A. variegatus* has been found in Fiji in these other situations:—

1. Leaf-axil of *Colocasia indica* (one record only).
2. Fresh water wells (P. H. Bahr 1913).
3. Coconut husk with rotting kernel (unusual).
4. Shell containing leaves.

* I feel certain that crab-holes must be widely used, because in mangrove swamps *A. variegatus* adults are usually very abundant and *Rhizophora* itself offers little scope in the way of water-holding cavities for the early stages of this mosquito.

The most frequently used, and therefore the most important, breeding-places of *A. variegatus* in Fiji are :—

1. Rot-holes in trees.
2. Old tins.
3. Coconut husks.
4. Crab-holes.
5. Rock-pools (important only on islands composed of coral rock).
6. Village gongs.

Of these breeding-places it would seem improbable that *Megarhinus* will frequent Nos. 3, 4 or 5 in the last list, and it is a matter for regret that these particular places—more especially coconut husks and crab-holes—are probably so largely responsible for maintaining the population of *A. variegatus* in places frequented by human beings. Recently I have found eggs laid by *Megarhinus* in a coconut plantation, both in split coconut husks and in those bored by rats. Although water remained in one of the split husks for three weeks after the eggs were discovered, the latter were washed out by rain; and in all the other husks in which eggs were found the water dried up within a few days. So that whilst possibly killing a few *Aedes* in split husks *Megarhinus* could only seldom, under very exceptional circumstances, mature in this situation, owing to the comparative rapidity with which water dries up after rain in a coconut husk.

From the standpoint of human health one would classify the breeding-places given in the last list in the following order of decreasing importance :—

1. Old tins.
2. Coconut husks.
3. Crab-holes.
4. Gongs.
5. Rot-holes in trees.
6. Rock-pools.

When this list is considered it will be realised that the reduction of *Aedes* in an ivi swamp, such as was probably brought about by *Megarhinus* at Waiyevo, is not going to contribute very materially towards a reduction of filariasis in Fiji, since tree-holes are relatively unimportant as breeding-places of *Aedes* from the public health standpoint. It is, however, possible that *Megarhinus* will render some assistance by reducing the numbers of *Aedes* breeding in tins and gongs. We found its eggs in large tins used for the liberation of colonies of pupae, and even quite a small tin, if well shaded, will hold water long enough to enable *Megarhinus* to undergo development. Native gongs will almost certainly become frequented by it when the mosquito becomes more generally distributed.

To sum up, we may say that, although there is really not the least probability that *Megarhinus* will bring about a wholesale destruction of *Aedes variegatus*, there is a chance that it may reduce the numbers of the filaria carrier by about 5 per cent. ; and if it does even that, the experiment of introducing it into Fiji will have been well justified.

7. The Life-Cycle of *Megarhinus splendens*.

With the exception of a few notes by various writers, mostly about the habits and habitat of its larvae, the only published account of the habits and biology of *M. splendens* seems to be that written by C. S. Banks in the Philippines in 1908, in which reference is made to this mosquito under the name *Worcesteria grata*, Banks (Banks

1908). The notes which comprise the subject-matter of this section of our report include some points in the study of *Megarhinus* not investigated by Banks, and some others in which our experience is at variance with his. But in many directions our investigations overlap his, and provide nothing new.

There is much concerned with the biology of *Megarhinus*—such, for instance, as its egg capacity and adult feeding habits—which requires further study. But notwithstanding the gaps in our knowledge about this insect which have yet to be filled, the studies of it which we have made during its introduction to and distribution in Fiji enable us to build up a more complete picture of the habits and biology of an important species of this most interesting genus of mosquitos.

Our investigations of *M. splendens* began in Java during the latter half of 1930, where the writer made studies of the life-cycle and feeding habits of larvae, and the occurrence of the early stages in the fields, and began to study the habits of the adults. In Fiji, during 1931, more detailed studies of the adults were carried out by Mr. J. C. Flemmons, who was able to devote some time to watching them on his tours of inspection of the breeding-sites in Suva. Much of what follows is the result of his work.

Emergence of Adults to first Oviposition.

Oviposition usually commences one week after the emergence of the adult. On one occasion (Lami, August, 1931) eggs were not found in the barrel in which pupae had been liberated until 28 days after the last adults had emerged. We were unable to find eggs anywhere else in the vicinity, and it is hardly possible that the eggs which eventually appeared in the barrels could have been laid by a female visitor from the nearest other colony site—more than a mile distant. It would seem that *M. splendens* has occasionally a long pre-oviposition life, possibly the result of inability to mate soon after emergence. Recently, on Taveuni, a five-day pre-oviposition period was noted; but we regard the normal period between emergence and the laying of the first eggs as one week. This agrees with the period given by Banks.

We have no exact record of the time which elapses between emergence and mating. We know that mating must often take place during the first two days of adult life; but the only instance of mating we have actually observed was between adults each three weeks old, although on one occasion, a male, three days old, made an unsuccessful attempt to mate with a newly emerged female in a small cage. The dates given by Banks (*l.c.*) indicate that mating must have taken place between individuals of less than seven days old.

Duration of Oviposition Period.

We obtained no individual records for the period of its life during which a female *Megarhinus* continues to lay eggs. At Walu Bay, adults of the original colony emerged from 11th March 1931 until about 10th April 1931. The eggs from this batch of adults were laid from 1st April 1931 continuously until 30th May 1931. There was, therefore, a period of about seven weeks between the date on which the last adults emerged and that on which oviposition ceased. Allowing for the usual pre-oviposition period of one week, it is indicated that egg-laying may continue over a period of about six weeks. At the Lami colony the last adults began to lay eggs about 12th May 1931, and freshly deposited eggs were found at this site repeatedly until 5th July 1931. As no other adults emerged in this locality between these dates, and as the tubs were five miles from the nearest other colony of *Megarhinus*, the results offer further evidence that females go on ovipositing over a period of several weeks. In contrast to the above records, however, it must be noted that Banks kept females in a jar from the time they emerged, and relates: "they lay 20 to 25 eggs per day for two days." In such confined conditions, however, it is not altogether surprising that the females completed their egg-laying so rapidly.

Longevity of Adults.

Apart from the rather general evidence just given that the females of *M. splendens* live for at least six weeks, I made a few records of longevity in Java with adults kept in captivity. The five longest-lived of these were :—3 males, which lived 33 days, 27 days and 22 days ; and 2 females, which lived 23 days and 25 (+) days.

Two other males and three other females were destroyed by spiders inside a large cage when they were less than two weeks old. These records were made with individuals kept inside a large cage with calico walls, measuring 6 ft. by 6 ft. by 4½ ft. wide, from which they were moved out on occasions into a glass jar—for not more than 24 hours—in order to see whether they would mate in a confined space. They were fed with banana, papaya and raisins, and an assortment of water-containing articles was kept in the cage. Since mating and oviposition never took place these records are of little value as an indication of the usual life of adults under natural conditions. But they lend support to our observations in Fiji, which indicate that the adult life of both sexes is at least several weeks.

The Egg Stage.

In the great majority of numerous records in Java and in Fiji the incubation period of *M. splendens* was two days. In a few instances the egg stage exceeded two days ; but in no instance was it more than three. On one occasion, when the actual laying and hatching of the egg was observed, the incubation period was 42 hours.

It seems remarkable to us that Banks gives the incubation period as four days, especially since his observations were made in the Philippine summer. He quotes one instance only of a two-day egg-stage. In all our records referred to above the eggs were kept in contact with water. An attempt has recently been made to ascertain whether eggs of *M. splendens* can withstand desiccation. Ten eggs, collected from tree-holes, were kept without water in a glass tube tightly stoppered with cotton-wool. Others, collected at the same time, were kept on water as controls. After 16 hours it was found that the chorion of the eggs kept dry had collapsed. They were then put on to water. Six of the eggs regained their shape, but none hatched, although kept for 9 days. All the eggs kept on water as controls hatched within 48 hours from the time they were collected.

It would appear from this experiment that the eggs of *Megarhinus* will not survive when removed from water. One would expect this to be so, since it would be of little advantage to the species if it could deposit eggs in situations subject to intermittent lack of water when its other immature stages occupy such a comparatively lengthy period.

The Larval Stages.

The larval period of *Megarhinus* varies within wide limits, depending very largely on the supply of food. The ability to survive a long period of more or less complete starvation is of enormous advantage to the larva in its natural surroundings, where the food supply is liable to intermittent failure. A total immature period of only 25 days under conditions of food abundance, and one of no less than five months under conditions of partial starvation represent the extremes in rate of development that we have observed. Between these limits perfectly normal development may take place in a longer or shorter time according to the rapidity with which the larvae are able to procure the food necessary for their growth.

In Table III are given figures (in days) for the larval stages of six individuals, one of which was reared at Buitenzorg in August 1930, and the remainder at Suva in August 1931. All these individuals were given as much food as they could eat. The mean temperature at Suva during the period of the experiment was 76°F. At Buitenzorg no exact record of the mean temperature was made ; but it cannot have been less than 79°F. The figures indicate that temperature does not influence the rate of development.

The figures in brackets in Table III denote the number of mosquito larvae (or pupae) eaten, or at any rate killed, by the *Megarhinus* during each stage of their development. The size of the larvae given as food was matched as nearly as possible with that of the *Megarhinus*, when the latter were small. But after they had reached their third instar the food consisted entirely of full-grown larvae or pupae of *Culex*, etc. Great care was taken to see that there was always a reserve of food with each larva; thus it can fairly be said that in these experiments the *Megarhinus* larvae consumed as much food as they possibly could.

The data given in Table III should be compared with those which appear in Table IV, dealing with larvae which were partly starved during some part of their development. The figures in this Table, unlike those in Table III, are derived from larvae which were kept in captivity only for a certain period of their development. Five were collected when in their first instar; fifteen when in their second; eight when in their third; and seven when in their last instar. They were all collected at Buitenzorg during the latter half of 1930, and are some of those which were used for tests to find out how long development could be delayed by restricting the food supply. The reduction of food was carried too far in several cases, and resulted in the death of the larva, or development into an abnormally small adult. The 35 larvae which supplied the data shown in Table IV all became perfectly normal adults, in spite of the fact that their development took so long.

TABLE III.
Instar Periods of, and Food eaten by, six Megarhinus splendens.

	In Java		In Fiji			
	1	2	3	4	5	6
1st instar ...	2 (13)	2 (6)	2 (13)	1.5 (9)	1.5 (8)	1.5 (10)
2nd " ...	3 (26)	3 (11)	2 (8)	3 (13)	3 (10)	3 (10)
3rd " ...	3 (17)	3 (10)	3 (13)	4 (12)	3 (16)	3 (14)
4th " ...	8 (100)	9 (79)	9 (88)	9.5 (109)	8.5 (96)	8.5 (86)
Total larval ...	16 (156)	17 (106)	16 (122)	18 (143)	16 (130)	16 (120)
Pupal ...	6	6	7	7	7	6
Sex ...	♂	♀	♀	♂	♀	♀

The figures for time are days. Those in brackets denote the number of mosquito larvae (or pupae) eaten during each instar.

In these experiments a regular supply of food was not maintained right through the development of each individual. They were supplied with from one to two *Culex* larvae a week or seven weeks after they had reached their third instar (or later, if they had been collected at an older stage), and then given about ten larvae a week until they pupated.

The very considerable difference in the rate of development between larvae which have as much food as they can eat and others which are more or less starved is well shown by the figures in Table V, which are derived from the individual records given in Table III, and those summarised in Table IV. It will be noticed that if only a tenth part of the maximum amount of food be given the period for larval development is increased about six times.

The average number of larvae eaten during the fourth instar works out at about 130 for those given abundant food, as compared with only about 40 for those whose food supply was restricted.

TABLE IV.
Instar Periods of and Food eaten by Megarhinus splendens Larvae used in Food Restriction Tests in Java.

	Collected when— 1st instar (5 larvae)			2nd instar (15 larvae)			3rd instar (8 larvae)			4th instar (7 larvae)		
	Max	Min.	Mean	Max	Min	Mean	Max	Min.	Mean	Max	Min.	Mean
1st instar	...	3 + (*)	2 + (*)	2.5 + (*)								
2nd "	...	35 (20)	21 (10)	29 (15)	25 + (11)	1 + (1)	10 + (6)					
3rd "	...	52 (15)	23 (9)	33 (13)	66 (20)	17 (5)	40 (13)	60 + (21)	2 + (0)	43 + (9)		
4th "	...	75 (83)	25 (33)	37 (48)	52 (51)	21 (22)	31 (35)	96 (56)	20 (27)	38 (40)	97 + (59)	34 + (3 +)
Total larval†...	134	82	97	101	72	81	98	73	81	97	34	62
Pupal	6	5	5.5	9	4	6	6	5	5.5	5	5	5
Sex	...	4 females 1 male		6 females 6 males 3 sex not recorded				3 females 4 males 1 sex not recorded			1 female 3 males 3 sex not recorded	

* Given as much food as could be eaten; numbers not recorded.

† These figures do not include that part of the larval life prior to the date on which the individual was collected.

‡ plus after figures indicates that the latter do not include the duration of (or food eaten during) that period of the instar prior to collection of the larva

The figures in brackets denote the number of mosquito larvae (pupae) eaten. Other figures denote time in days.

The very considerable difference in their rate of development displayed by these two sets of *Megarhinus* larvae kept in captivity must occur, to some extent, amongst larvae living under natural conditions. No useful object can, therefore, be gained by attempting to arrive at a figure for a normal, mean rate of development from the data which are set forth in Tables III and IV above. I consider that the mean figure of 16.5 days for the total larval period, as given in Table III, represents the usual duration of the larval stages of those individuals which are fortunate enough to be able to avail themselves of an abundant supply of food. Others, less fortunate, may take as long as four or five months to complete their development.

Banks gives the duration of the fourth instar as five to eight days. None of the individuals bred by us have required so little as 5 days for this instar. For the other instars Banks' records agree to within a day with those made by us.

TABLE V.

Comparison of the Duration of Larval and Pupal Periods, and of the Feeding Rate, between full-fed and partly starved Individuals of Megarhinus splendens.

	Food abundant			Food reduced		
	Duration of development		Mean rate of feeding*	Duration of development		Mean rate of feeding*
	Mean	Min.		Mean	Max.	
1st instar ...	2	1.5	5.6	—	—	—
2nd „ ...	3	2	4.6	29	35	0.5
3rd „ ...	3	3	4.3	39	66	0.3
4th „ ...	9	8	10.5	34	96	1.1
Total larval ...	16.5	16	7.7	105 †	134	0.75 ‡
Pupal ...	6.5	6	—	5.7	9	—

* The unit is one *Culex* larva (or pupa) a day.

† This figure is computed from the sum of the mean figures given above plus an allowance of 3 days for the first instar.

‡ This figure is obtained from the total food eaten divided by the total duration of development in days for all completed instars of 28 larvae.

A point of interest in the development of the 4th instar larva is that when pre-pupal, *i.e.*, about 3 to 4 days before the pupal moult, the sides of the thorax lose the deep red colour characteristic of the larva up till this time. The paler sides of the thorax just before pupation produce an altered effect in the shape of the larva, which looks as if its body were of even width from the head back to the central part of the abdomen. It is unlikely that this change in colour of the larva is characteristic only of this particular species.

The Pupal Stage.

From 5 to 7 days is the usual duration of the pupal stage of *M. splendens*. From those individuals of which the pupal periods are given in Tables IV and V the following data are obtained :—

	Max.	Min.	Mean
Pupal period (34 individuals) ...	9 days	4 days	5.7 days

Banks gives five to six days as the pupal period in the Philippines.

8. Notes on Habits and Biology of *Megarhinus*.

The Adults.

Adults of *Megarhinus* are diurnal in habit. Those of *M. splendens* rest at night on the trunks of trees or other objects near the places in which they lay their eggs. They

move off with a shrill buzz at the approach of danger. The buzz made by *Megarhinus* is a good deal louder than that made by most mosquitos, and has a rather plaintive air about it.

M. splendens shows a certain reluctance to fly, although its flight is quite strong when once it has taken to the wing. When disturbed from their usual position of rest on a tree-trunk they will often fly once or twice round the tree and then settle again in almost the same position. If there is nothing to bar their flight they may make their way to a neighbouring tree; but nowhere have we met with them far away from the place where they spent their immature life. It would seem that this species has acquired its wide distribution rather from an ability to use a comparatively large assortment of breeding-places than from any powers of flight it may possess.

It is surprising how inconspicuous an adult *M. splendens* is when resting on the trunk of a tree. The brilliant metallic colours of its body, visible on close inspection, blend into a dark greenish tint when viewed at more than a few inches distant.

They feed, apparently, solely on the surface moisture of plants. We have, unfortunately, never seen adults feeding in the field; but in captivity they feed on the juice of various fruits, settling in quite a friendly manner on slices of banana or papaya held in the hand. They would often settle on the back of the hand and search with their proboscis, which is then extended straight, for the perspiration which usually forms there when one remains for any length of time inside a calico-walled cage in the tropics.

It is interesting to note that Banks made dissections of the proboscis of *M. splendens* with the object of ascertaining whether this mosquito is structurally equipped for sucking blood. He found that, whilst retaining some of the modifications found in the blood-sucking mosquitos, in other respects the mechanism for obtaining such food was not developed. Although an occasional reference in older literature remarks a blood-sucking habit for *Megarhinus*, there is no authenticated instance of this, and the genus as a whole displays a structural modification of the proboscis which renders its species ill-equipped for the piercing of skin necessary to obtain a feed of blood.

Unlike most mosquitos, which mate whilst flying, *M. splendens* mates when settled. Coition lasted two minutes during the only instance of mating that we have observed.

In spite of repeated efforts I was unable to get adults to mate in captivity, and am surprised that they should have done so in a glass jar, as reported by Banks (*l.c.*). I tried keeping the sexes together in varying numbers in glass jars; in a small calico-walled cage (measuring 10 by 6 by 6 inches) and in a larger one (measuring 6 by 4 by 6 feet), in which were kept sections of bamboo, an enamel basin and a large tin—all full of water and mosquito larvae; and finally in a large mosquito-proofed stable (24 by 12 by 6 feet), also provided with suitable places for oviposition. In no case were eggs laid; and it would seem most probable, that this was due to the fact that mating never took place. But, as we have noted above (p. 22), in one instance a 3 days old male attempted to mate with a newly emerged female, when the latter was released in a small cage; but in this case the female did not appear to be ready to mate and would not allow the male to achieve coitus.

The oviposition habits of *M. splendens* are remarkably interesting. The eggs are dropped on to the surface of water from a height of two or three inches, the female hovering in this position usually near to the edge of the tree-hole or other place selected for oviposition. We have found eggs in tree-holes of such small size that it would not be possible for an adult *Megarhinus* to hover on the wing within them. Eggs must in these instances have been dropped into the hole from the outside. This probably also happens when eggs are laid in small bamboo stumps and leaf-axils of *Colocasia*.

We have seen oviposition taking place only in the afternoon. Possibly it may occur at any time during the day ; but it is unlikely that oviposition ever takes place at night, although on one occasion a female was surprised at a tree-hole inspected at 10 p.m. by torchlight. Eggs had been deposited in this hole since the morning of the same day, but it is not certain that they were laid after dark, and the circumstances relating to this particular instance were unusual, because a scarcity of other breeding-places in the immediate neighbourhood, coupled with the fact that people were working in close proximity to the tree-hole most of the day, may have driven the female *Megarhinus* to visit the hole after dark.

In Fiji oviposition was noted to be most prolific in sunny weather, much less so in dull weather, and during rains very few eggs were laid.

We made the following notes in Suva on the rapidity with which oviposition takes place.

(i). 30th June, 1931. 12.30 p.m. Overcast. Three eggs were deposited in succession at intervals of one minute. After a rest of 5 minutes on outside of tub two more were deposited at similar intervals (5 eggs in 10 minutes).

(ii). 13th July, 1931. 3.30 p.m. Sunny. Eight eggs were deposited at ten second intervals ; after a rest of 5 minutes, 5 more were deposited ; and after another rest of 5 minutes 3 more were laid (16 eggs in about 12 minutes).

(iii). 31st July, 1931. 2.30 p.m. Sunny. 10 eggs were deposited in succession at intervals of 15 seconds (10 eggs in 2½ minutes).

It was observed that a female would sometimes touch the surface of the water with the tip of her abdomen during a period of egg-laying. It appeared that by moistening the tip of the abdomen ejection of eggs was facilitated. Possibly, however, the lateral hair-tufts at the end of the abdomen may have a sensory function and be used to ascertain some physical or chemical property of the water in which a female is about to oviposit. Never does a female alight on the surface of the water to lay its eggs.

In the earlier part of this account I have discussed those habits of *M. splendens* which concern its choice of breeding-places. All that need be added here is to remark on the considerable wastage of eggs which normally seems to occur. It is not uncommon to find upwards of 20 eggs on the water of one tree-hole, and only in the largest holes is there ever sufficient food to enable that number of larvae to mature. Certain tree-holes seem to be especially attractive, egg after egg being dropped in such a place, whilst other holes near by, with apparently all the attributes of a suitable breeding-place, receive none.

The Eggs.

The egg of *M. splendens* has been described by Banks, and we have nothing to add to his account of its morphology. When unhatched, eggs are fairly conspicuous objects on the surface of the water in dark tree-holes owing to their lustrous white chorion. The latter splits into two equal, hemispherical portions on hatching, and it then loses much of its brilliance and appears as a pair of dull white discs floating on the surface of the water. The two halves of the egg soon afterwards become separated from each other.

Owing to the extreme mobility of the eggs on the surface, film air currents are liable to drive them to the leeward side of the water on which they are laid ; moreover, their extremely light weight renders them subject to the attraction of the much heavier egg-rafts of *Culex*, to which they are often found attached. They are very liable to be washed out of a tree-hole, coconut husk or any other exposed situation in which they may have been laid, by heavy rains. In one tree-hole kept under observation continuously for eight weeks seventeen eggs were laid and not a single *Megarhinus* larva hatched, all the eggs being splashed out by rain. Even when the eggs are left

attached to the walls of a tree-hole by the gradual lowering of the water-level through evaporation hatching seems to be prevented. So far as we have been able to discover, the eggs cannot resist desiccation (p. 23).

The Larvae.

The larvae of *Megarhinus* are purely predatory as regards their food. Their mouth-parts are structurally modified to enable them to catch hold on to living objects which come within their reach. They apprise the proximity of their prey with the aid of long setae which project from the sides of the thorax; and when hungry they will stealthily approach the scene of any disturbance in the water which they have been able to discern. Although frequently to be seen lying deep down at the bottom of a tree-hole their customary position when searching for food is at the surface. In this position they can detect disturbances in the surface film of the water made by mosquito larvae or pupae coming up to breathe. It is remarkable that Banks should have met with no instance of cannibalism. We have observed it very frequently—both in the field and laboratory—and one cannot assign to *Megarhinus* any powers of discernment which enable it to avoid its own species in its search for food.

TABLE VI.
Starvation Tests with Larvae of Megarhinus splendens in Java.

	Stage when collected	Period in* captivity before complete starvation began	Stage when starvation began	No. of days with no food at all	Time from end of starvation period until pupation or death	Fate of larva
1	4th	28 days	4th	4	4 days	Matured
2	4th	74 ..	4th	3	3 ..	..
3	4th	74 ..	4th	9	9 ..	..
4	4th	42 ..	4th	18	18 ..	..
5	3rd	52 ..	4th	21	54* ..	..
6	4th	28 ..	4th	52	31 ..	Died
7	4th	28 ..	4th	52	32 ..	..
8	3rd	39 ..	4th	21	6 ..	..
9	3rd	44 ..	3rd	21	20 ..	..
10	3rd	44 ..	3rd	19	0 ..	..

* Kept during this period on a diet of two larvae a week.

We have stated above that *M. splendens* will feed on such fundamentally different animals as a tadpole and a mosquito larva. We tried holding a freshly killed *Culex* larva near the head of a third instar *Megarhinus*, and it was eaten with relish; but larvae feed mainly on living organisms, and the larvae of other mosquitos form the bulk of their food. Even very young larvae are capable of catching and eventually killing *Culex* larvae twice their size. On one occasion third instar *Megarhinus* were given *Aedes* larvae fully twice their length; the *Aedes* were caught and eaten in each instance. In the case of one larva the meal continued for a whole day, at the end of which time the carcass of the *Aedes* was discarded almost whole.

Not the least remarkable feature of the larvae of *Megarhinus* is their ability to survive for long periods without food. We made several tests of this at Buitenzorg, and give data in Table VI. Two of the larvae whose history is recorded in this table remained alive for no less than seven weeks with no food at all. They then fed at the rate of two larvae a week for four weeks, after which they died. Ability to survive without food is much less when the larvae are in their first or second instar. Such larvae died, on occasions, when starved for only three days; whereas a fourth stage larva (No. 5 in Table VI) matured in a healthy condition after having been completely starved for three weeks.

Summary.

1. In 1927 a suggestion was made by P. A. Buxton to introduce *Megarhinus* to Samoa and Fiji for the control of *Aedes scutellaris* (*variegatus*), which transmits human filariasis.
2. In 1929, C. E. Pemberton introduced *M. inornatus* from New Britain into Hawaii, where it has apparently failed to become established.
3. In the same year the writer was sent to Java to obtain parasites for a coconut pest in Fiji; and in 1930 received instructions from the Fiji Government to collect and transport *Megarhinus* from Java to Fiji.
4. During the latter half of 1930 early stages of *Megarhinus splendens*—the commonest and most widespread species in Java—were collected from tree-holes, bamboo stumps and tubs at Buitenzorg.
5. Experiments were conducted at Buitenzorg to ascertain how long the larvae could be kept in a healthy condition by restricting their food supply. It was found that they matured normally on a reduced diet after a development lasting as long as two months. The most rapid development from egg to adult was found to take 24 days. Attempts to breed the adults in captivity were unsuccessful.
6. In January 1931, a colony of *M. splendens* consisting of 283 larvae was taken to Fiji; 45 died or emerged as adults during the voyage of 28 days.
7. On 27th February 1931, 238 *M. splendens* were landed at Suva.
8. Colonies for distribution to various parts of Fiji were bred in Suva during 1931 and 1932, and by April of the latter year 51 colonies, composed of nearly 3,000 individuals, had been liberated.
9. *Megarhinus* was bred at Suva by liberating the pupae in barrels kept out of doors. The adults which emerged laid most of their eggs in the barrels in the absence of other breeding-places in the vicinity. The larvae were collected from the barrels when they reached their third instar. They were fed in captivity until they pupated, and then liberated as pupae in colonies sent to various parts of the group.
10. By the end of 1931 *Megarhinus* had been recovered at six of the colony sites in natural breeding-places, and is now well established. The most favourable type of country in Fiji for *Megarhinus* to colonise is the swamp land with trees of *Inocarpus edulis* ("ivi"), which occurs near the coast on many islands.
11. An account is given of the spread of *Megarhinus* through an *Inocarpus* swamp on the island of Taveuni, where a survey was made of the *Megarhinus* and *Aedes* content of all the tree-holes within six feet of the ground. *M. splendens* was present in rather more than 50 per cent. of the holes and *Aedes variegatus* in about 40 per cent. The probability is that in this locality *Megarhinus* has caused a 20 per cent. reduction in the number of tree-holes containing *Aedes* during the three months succeeding its liberation.
12. It was found that in most places, in the forest especially, *Megarhinus* spreads very slowly—undergrowth making an effective barrier to its flight.

13. *A. variegatus* breeds mostly in tree-holes, tins, holes in rocks, coconut husks, wooden gongs in native villages and crab-holes (the last not yet proved in Fiji). Of these places *Megarhinus* has so far bred only in tree-holes and tins (very occasionally). It will probably breed in native gongs but unlikely that it will breed in either crab-holes, rock-pools or coconut husks. Therefore at the best it can hardly be expected to reduce the numbers of *A. variegatus* in Fiji by more than 5 per cent. But even that would justify the trifling expenditure which has been devoted to the project.

14. Studies of the habits and life-cycle of *M. splendens* made in Java and Fiji revealed the following points of interest :—Incubation period always about 2 days ; larval stages, minimum 16 days (food abundant), maximum 134 days (food scarce) ; pupal stage always about 6 days. The minimum period for a generation is about 30 days.

In spite of the lower average temperature in Fiji very little difference was noted between the rate of development in that country and in Java.

The adults are diurnal in habit. They mate when settled ; not on the wing, as do most mosquitos. The eggs are dropped singly on water where they float on the surface film. They are almost round and glossy white. Oviposition continues over several weeks, and is most prolific in sunny weather. The egg capacity was not determined.

Larvae of *Megarhinus* fed on tadpoles, Tipulid larvae, *Chironomus* larvae, and all sorts of mosquito larvae. They do not object to feeding on those mosquito larvae whose bodies are very hairy. They are cannibalistic.

15. In May 1933 a small colony of *M. inornatus* was brought by the writer from Rabaul to Fiji, since it was reported that this species had been found in New Britain breeding in coconut husks. This species is now being bred in Suva, whence, if it survives, it will be distributed to other parts of the group. Its immature stages are of similar duration to those of *M. splendens*, so that it would seem very unlikely that this species will succeed in reaching maturity in coconut husks in Fiji, complete evaporation of the water taking place too quickly.

M. inornatus is structurally very close to *M. splendens*, and it is quite possible that the two species will eventually hybridise in Fiji.

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EXPLANATION OF PLATE I.

- Fig. 1. Holes in the buttress roots of *Canarium decumanum* in the Botanical Gardens at Buitenzorg, Java.

Megarhinus splendens was collected from these holes, the water in one of which can be seen in the photograph. The knife at the back of the hole is six inches long.

- Fig. 2. Colony site at Waiyevo, Taveuni (Fiji), where *M. splendens* was liberated in July 1931. The tub, which contained the pupae liberated, is at the base of an "Ivi" tree (*Inocarpus edulis*), the trunk of which contained no less than thirteen water-holding cavities within six feet of the ground.

Note the piece cut out from the side of the tub on to which wire gauze was nailed to allow water to overflow after rains without washing out the eggs of *Megarhinus*.

- Fig. 3. An "Ivi" tree at Waiyevo, Taveuni. In this swamp *Megarhinus* became established and spread rapidly (*vid.* p. 14 *et seq.*). A feature of these swamps is the absence of undergrowth. A moderate amount of sunlight penetrates through to the ground, the light-coloured blotches on the photograph being caused by patches of sunlight.



Fig. 1.



Fig. 2.



Fig. 3.

THE SUGAR-CANE MOTH BORERS IN MAURITIUS.

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(PLATE II.)

Introduction.

During the course of the last five years, sugar-planters in Mauritius have had to sustain heavy damages caused by moth borers of the sugar-cane. The present publication is intended to bring up to date the available information respecting the status of moth borers and the control measures adopted against them in this island.

Circulars were addressed to all planters concerned, seeking an expression of their long experience and their observations on these pests. In the following pages are summarised the results of this enquiry.

From the year 1928 to 1931, the method adopted to estimate the percentage of cane attacked by the spotted borer, *Diatraea venosata*, Wlk., was the usual method of counting the number of cane-stalks punctured per 100 units. This method has various drawbacks, in that it gives a false idea of the incidence of the spotted borer attacks, particularly respecting the different varieties of canes, as one variety may be more susceptible than another. The method has nevertheless had the advantage of showing that there was a gradual, annual increase of the spotted borer in the island.

From 1932, a new method, devised by Dr. Wolcott in Porto Rico, has been initiated ; it consists in estimating the number of canes attacked per 100 lb. of cane : the results of the survey on these new lines are discussed below.

The author wishes to tender his thanks to the various planters who showed keen interest in this work ; to the officers of the Botanical and Entomological Divisions of this Department for their valuable help in the survey carried out over the whole island ; and to officers of the Sugar Technological Division for the various chemical analyses of canes they have performed.

Historical.

The first serious outbreak of moth-borers in Mauritius was noticed in the year 1856, with the attacks of the spotted borer, *Diatraea venosata*, Wlk. (*Proceras sacchariphaga*, Bojer). This insect had probably been introduced a few years before (presumably in some consignment of new cane varieties received from Ceylon), and cane-planters sustained heavy losses from it. Two other moth borers were subsequently introduced, namely the pink borer, *Sesamia vuleria*, Stoll, and the white borer, *Grapholita schistaceana*, Sn., the latter, which is the more recent, having appeared in 1897.

The local climatic and other environmental conditions seemed to be most favourable to the development of these insects, as they increased rapidly in the island without being checked apparently by the numerous factors which, in their country of origin, most probably held them under control.

From 1897 to 1916, although the incidence of borers had decreased yearly in intensity, yet the damage caused by them remained very appreciable. From 1916 to 1928, through a better knowledge of the habits of these insects and of their parasites, coupled with measures of control adequate to each species, these borers in Mauritius were kept under control to such an extent that they were considered by planters as

pests of minor importance. This somewhat too optimistic idea coincided unfortunately with the prosperous years of the sugar industry in the Colony, when planters were more anxious to increase their areas under cane cultivation than to carry out field work for borer control. These pests therefore increased, especially where certain fields had to be abandoned subsequent to the fall in the price of sugar. The result was that the abandoned fields served as permanent foci of infestation throughout the island.

This state of affairs explains the outbreaks of borers noticed during the last few years. Of the three species, *Diatraea venosata* has increased in numbers to such an extent as to become a serious menace to sugar-cane cultivation in Mauritius.

The following table shows the figures recorded from 1928 to 1931 on the various estates of the island regarding the incidence of *Diatraea venosata* and the red rot disease, a fungus disease consequent on the borer attacks.

Years	Attacks of spotted borer % canes						Attacks of red rot % canes					
	W.T.	DK 74	M.131	M.55	RP.8	D.109	W.T.	DK.74	M.131	M.55	RP.8	D.109
1928	8.0	16.5	12.4	9.4	—	—	2.5	6.6	2.9	0.8	—	—
1930	17.0	31.7	25.9	31.9	31.0	56.0	2.1	4.5	2.1	1.6	0.6	2.9
1931	28.0	39.0	38.0	38.0	39.0	77.0	8.1	19.0	7.0	5.0	6.0	17.0

Distribution and Incidence of Borers.

From observations made during the last few years (1928 to 1932) all over the island, it is evident that the relative importance of the three moth borers is as follows :—(1) spotted borer, *Diatraea venosata*, Wlk., (2) pink borer, *Sesamia vuteria*, Stoll, (3) white borer, *Grapholita schistaceana*, Sn.

Diatraea venosata does not attack mature canes only, as is generally believed ; young canes are also attacked, especially those produced from infested cuttings. *Sesamia vuteria*, which is of minor importance now, attacks young canes and young shoots ; and *Grapholita schistaceana* is generally of minor importance, in spite of the fact that young plantations, as soon as they sprout from the soil, are occasionally heavily attacked by it.

The distribution of these three species in the island is correlated with the rainfall, temperature, and altitude.

Table I of the Appendix shows that in the central part of the island, where rainfall is high, temperature low and altitude elevated, the three species of borers exist but the damage caused by them is negligible. On the coast belt, *Diatraea venosata* occurs with high intensity during April to July, *i.e.*, during the cold and dry season. At medium and low altitudes *Sesamia vuteria* occurs with intensity from December to April, *i.e.*, during the hot and rainy season, and is very scarce during the dry season, when there are few weeds in the fields and the canes are tall. The incidence of *Grapholita schistaceana* is uniform all over the island and is of very slight intensity ; from December to April, however, some sporadic outbreaks of this insect are observed in certain localities.

Biology of Borers.

Diatraea venosata, Wlk.

The number of eggs laid by a female *Diatraea venosata* varies from 150 to 200. The laying takes place at several intervals during a period of 8 to 10 days.

The eggs are laid just as freely on either of the leaf surfaces or on the cane stem. They are grouped in clusters varying from 10 to 30 eggs, arranged in two imbricated rows. They are elliptical, flattened, of a light yellowish green colour and measure 1.6 mm. in length, and hatch after seven to nine days.

The newly hatched larvae are small and measure 1.2 to 1.4 mm. in length and 0.4 mm. in width at the head and 0.2 mm. at the end of the abdomen. When fully developed, the larvae of *Diatraea venosata* measure from 25 to 30 mm. in length and 3.5 mm. in width; they are white and marked with rhomboidal brown spots (four to six on each segment).

The larval stage lasts from 25 to 30 days. The newly hatched larvae attack the unexpanded leaf; thereafter they reach the stem, boring in sinuous galleries in the portion situated beneath the sheaths. One larva may attack several stems, thus accentuating the injury.

Pupation takes place outside of the stem, generally between dried leaves. The chrysalis is yellowish red and measures 15 to 18 mm. in length and 4 mm. in width. The nymphal period lasts from 15 to 25 days.

The moths are lucifugous, hiding among dry leaves during the day, and do not fly long distances.

The host-plants are the following:—*Vetiveria* (*Andropogon muricatus*, Retz.), *Fataque* (*Panicum maximum*, Jacq.), and maize (*Zea mays*, L.).

Sesamia vuteria, Stoll.

The female seldom lays its eggs on young canes but always under the leaf-sheaths of graminaceous weeds. They are arranged in two or three contiguous rows of 10 to 75 eggs, and measure 0.7 mm. in length. Their shape is oblate, being flattened at the opposite poles and deeply striated all round; they are white when newly laid. The incubation period varies from 8 to 10 days. When newly hatched, the young larvae measure 2 mm. in length by 0.4 mm. in width. During the first days of their life they remain on the weeds, thereafter leaving these plants to attack the stems and shoots of young canes, eating the central part and causing subsequent wilting. As these borers cannot live in a decaying stem, they leave it and pass on into one or more other healthy canes until they reach their full size. When fully grown the caterpillars measure 25 to 30 mm. in length, and the upper side of the body is of a pink violet colour—hence the name of pink borer. The head is brown and smaller than the other segments of the body, the sides and the undersurface of the body being both tinged with yellow. The complete life-cycle of the larva lasts 30 to 40 days. The pupa is uniform brown and measures 18 to 20 mm. in length by 4 mm. in width. It is generally found in a cocoon made up of various debris cemented together by means of silken threads. The nymphal period lasts 12 to 15 days.

The adults are sedentary and fly but little. They dislike sunlight and hide amongst dry straw and other rubbish in the fields.

The principal host-plants in Mauritius are:—Maize (*Zea mays*, L.), *Vetiveria* (*Andropogon muricatus*, Retz.), Rye grass (*Lolium* sp.), Herbe Collier (*Coix lachrymans*, L.), Herbe bambou (*Setaria* spp.), *Fataque* (*Panicum maximum*, Jacq.), Herbe millet (*Setaria* spp.), and Herbe cato (*Cenchrus echinatus*, L.).

Grapholita schistaceana, Snell.

The eggs of this moth are laid singly, or by twos, on the leaves, as well as on the stem. The egg is oval and measures 1.4 mm. in length by 0.7 mm. in breadth. It is of a yellow colour, which blends with the colour of the leaves. The incubation period is 5 to 7 days.

The newly hatched larva is of a yellowish grey colour, with the head, thorax and legs brownish. As soon as it hatches, the larva crawls down the plant and enters the

underground portion of the shoot. After eating the periphery in an ascending spiral gallery, the larva reaches the central portion of the stalk, causing wilting of the whole shoot. As a rule the cane is attacked as soon as the young shoots sprout from the soil. The larva reaches its full size after 25 to 30 days and measures 15 to 20 mm. in length and 2 mm. in breadth. It is of a uniform dusty-white, bordering sometimes on yellow.

The pupa is reddish yellow and measures 8 to 10 mm. in length by 3 in width. It is enclosed in a silky brown cocoon spun by the caterpillar at the exit of its breeding gallery. The nymphal stage lasts 10 to 12 days.

Parasites.

The most common natural enemies of these three species of borers are insects parasitising either eggs or larvae. The following table indicates the incidence of their parasitism in Mauritius.

		Parasites	Spotted borer	Pink borer	White borer
Eggs	...	<i>Prophanurus alecto</i> , Craw.	+	+	—
		<i>Trichogramma australicum</i> , Gir.	+	+	+
Larvae	...	<i>Apanteles simplicis</i> , Vier.	+	—	—
		<i>Henicospilus antankarus</i> , Sauss.	+	+	—
		<i>Ophion mauritii</i> , Sauss.	+	+	—

+ = Parasitised.

— = Not parasitised.

Prophanurus alecto, Craw.—This parasite occurs in numbers varying with the locality; it is more common on the pink borer than on the other borers. The percentage of parasitism sometimes reaches 60. The life-cycle lasts 14 to 16 days. The number of parasites per egg is sometimes two.

Trichogramma australicum, Girault.—This species parasitises the eggs of all three species of borer but more frequently those of the spotted borer. During certain months of the year, in localities heavily infested by this pest, the parasitism reaches 75 to 90 per cent. The life-cycle of this species takes 6 to 8 days in summer. The number of wasps contained in a single egg varies from 2 to 4, according to the species of borer.

Apanteles simplicis, Vier.—This parasite oviposits exclusively in the larvae of the spotted borer. The number of cocoons present on a *Diatraea* larva varies between 60 and 75. This parasite is rather scarce and not well disseminated in the island.

Henicospilus antankarus, Sauss.—This species attacks the larvae of the pink borer as well as those of the spotted borer. It is more common during summer, from January to April, when the percentage of parasitised borers reaches sometimes 60. At other periods of the year parasitism varies from 0 to 15 per cent.

Ophion (Stauropodoctonus) mauritii, Sauss.—This parasite is less common than *H. antankarus* and attacks the spotted borer as well as the pink one. Its biology has not been worked out.

In addition to the above-named parasites, a Tachinid fly has been recorded as attacking the pupae of these three borers. The author has found it impossible to observe this fly, probably on account of its extreme rarity.

The incidence of all these parasites in Mauritius is closely related to the climatic conditions, which vary considerably with the different localities. It is believed that cyclones exert an influence in decreasing the number of parasites, thereby producing sporadic outbreaks of borers in some localities.

Economic Importance of Moth Borers.

As *Diatraea venosata* is the species which has specially attracted the attention of planters for the last four to six years, the damage and the losses caused by it will be discussed here more particularly. Table II shows the actual status of this pest in Mauritius. The observations were made on canes in the fields at the time of reaping as well as on samples taken at the mill carriers. As previously mentioned, the degree of incidence of this borer was determined this year in accordance with the method recommended by Dr. Wolcott for estimating the damage done by *Diatraea saccharalis*, F., in Porto Rico, a species that behaves very similarly to *D. venosata* of Mauritius.

By this method the number of borers is calculated by taking for granted that each hole in a stem represents the damage of one borer in the cane. A correction is made for the possible errors due to the weight and number of canes. This correction varies with the varieties and the intensity of the attack.

Investigations along these lines revealed that the number of borers per hundred pounds of cane varies between 4 and 89 according to the cane variety; and the mean of borers per hundred pounds of cane is 40 for the year 1932.

The number of borers per acre varies between 1,600 and 35,000, and the mean figure is 15,600. The cane varieties more susceptible to the attack of the spotted borer are the following:—M.55, M.131, D.109, M.1474, White Tanna, BH.10/12, D.K.74, R.P.6, D.130 and R.P.8. The percentage of canes attacked by 1 to 5, 6 to 10, 11 to 20 borers is 87.6, 10.1 and 2.2, respectively.

Estimations made in the field during the reaping season showed that in certain localities 60 to 70 per cent. of the canes were attacked by borers, and as a mean for the whole island, 30 per cent. of the canes are attacked. The percentage of nodes attacked varies between 10 and 25. The reduction of yield per acre is between 15 and 20 per cent. in severely infested localities. The maximum reduction recorded has been 75 per cent. on an highly infested estate.

To the losses incurred in the fields must be added losses in the course of sugar manufacture as a consequence of the borer attacks. These losses are:—(a) a decrease in the sucrose content, (b) a decrease in the juice, (c) an injurious effect due to fermented juice or to rapidly fermenting juice, caused by red rot, a fungous disease which follows attacks by borers.

Table III shows a comparison between results of the analysis of healthy canes, and of canes attacked by *Diatraea venosata*. The three analyses made show that the average loss of sugar per cent. canes is 2.28, i.e., a decrease of 16 per cent. in the sugar content of the cane. Consequently the purity of the juice decreases and the glucose content increases in the attacked canes. Taking as an average a loss of 2.3 of the sucrose per cent. cane and a proportion of attacked canes of 30 per cent., and estimating an annual cane production of 2,500,000 tons, the loss of sugar in cane is about 15,000 tons, which means a net loss of about 14,000 tons with a recovery of 83 per cent. It follows that the gross loss is 1,500,000 rupees, and reckoning the sale price at Rs.6.00 per cwt. of sugar, the net loss would approximate to Rs.140,000 (estimating the cost of production at Rs.5.50 per cwt.).

The losses due to the pink and white borers are difficult to estimate in view of the fact that plants are being attacked when quite young, and are capable of some recovery during their subsequent growth.

Losses are really felt by planters only when the shoots die through successive attacks, in which case the field has to be replanted or the shoots destroyed by the borers have to be replaced. To these losses due to the pink borer must sometimes be added the cost of applying to the fields various control measures adopted to keep the borers in check. These measures consist in the collecting and destruction of larvae and the cultivation of maize as trap plants. About Rs.5.00 or 6.00 an acre are spent annually on certain estates for the control of the pink and white borers. This would mean an annual expenditure of Rs.8,000 on estates of an extent of 1,800 acres under cultivation—an expenditure sufficiently high to engage the attention of planters concerned.

Control Measures.

These may be summarised as follows :—

- (a) Destruction of eggs and larvae by means of trap plants.
- (b) Destruction of larvae by hand collection.
- (c) Straw burning.
- (d) Destruction of injurious grasses and weeds which harbour the pest.
- (e) Rotation of crops and interline cultivation.
- (f) Breeding of parasites.
- (g) Selection of borer-free tops for planting.

The Destruction of Eggs and Larvae by means of Trap Crops.

Maize is the plant which attracts borers in greatest numbers. The following directions should be strictly observed in order to obtain good results :—

1. The sowings should be effected previous to, or simultaneously with, the planting of the cuttings, according to the kinds of weeds that were growing in the field before planting or which are there at the time of planting.
2. They should not be made at the time of weeding, but previous to it, in order to attract borers when they forsake the withered weeds and take to young canes.
3. The quantity of seeds per arpent and the number of rows of trap plants depend upon the estimated degree of infestation of the field. As a rule 5 lb. of seed are sufficient for an arpent ; the sowings should be made on a strip all round the field.
4. The sowings should be made in rows in the interlines at intervals of two to three inches all along.
5. The uprooting and removal of the infested maize plants should be performed daily or at least every three or four days. As the eggs laid under the leaf-sheaths hatch after 8 or 10 days, the young larvae bore directly into the heart, and the plant withers. A group of larvae can be thus observed easily.

Trap plants have been in use for many years on various estates. The results obtained against the attacks of the three species of borers have been always satisfactory but more pronounced in the case of the pink and white borers. When properly carried out, and in due time, this method is really efficient against these two pests.

The Destruction of Larvae by Hand-collecting.

From enquiries made on this subject it would appear that, in certain parts of the Island, a marked decrease has been observed after the hand collection of larvae in plantations heavily infested by the pink borer and in young plantations attacked by the spotted borer. But on the other hand, similar results were obtained by other planters who did not practise this method of destruction. These contradictory results

may perhaps be due to the different climatic conditions existing in the various parts of the Island. It is nevertheless necessary to support those who have observed the benefits derived on their plantations from this method as regards the pink and white borers.

In order to obtain good results it would be necessary to collect the borers as soon as the infestation is noticed and to continue the collection all the season round, *i.e.*, from December to April every year. Hand collection should not be attempted in highly infested fields, as the principle of this method is to destroy the insect in its first brood, thus preventing any subsequent broods. The removal of the withered stems should be made by cutting them as near as possible to the surface of the soil so as to diminish the chances of leaving borers in the basal parts of the stem. All the attacked stems should be burned after the removal of the larvae in them.

Straw-burning.

As in the previous case, there is considerable diversity of opinion as to the value of this method. Several planters report that they have noticed a decrease in infestation when no burning of the straw in cane-fields was practised; on the contrary, others recommend straw-burning as an efficient method of control. However, it should be remarked that by burning the straw, a large number of borer parasites are also destroyed. In Cuba a reduction of 50 per cent. in the infestation was noticed in fields where no burning had been practised.

Weeding of Graminaceous Plants.

The usual practice for preventing infestation by borers in cane-fields, especially by the pink and white borers, consists in keeping the field in a relatively clean condition by weeding out these graminaceous plants that harbour the borers. This method has already given good results in Mauritius, though some planters complain, without reason, of its inefficiency. The causes of failure are very often due to the faulty application of the method. After their removal the weeds should be destroyed so as to kill the borers in them, otherwise the borers would leave the withered weeds to attack young canes. In a newly planted field and one where weeding has been performed, these natural host plants of the borers should be replaced by maize as a trap crop, otherwise it may happen that the newly hatched borer moths may lay their eggs directly on the young cane stems in the absence of the weeds usually selected for this purpose.

Rotation of Crops and Interline Cultivation.

These two methods have been found to give good results in borer control. Their use is, unfortunately, limited in certain localities on account of the fact that only very few fields can be left fallow. The cultivation in interline of certain plants, such as potatoes or tomatoes, is not of much benefit on account of cryptogamic diseases prevailing on these plants.

Selection of Borer-free Tops.

Some planters do not realise the disastrous effects which follow when cane-tops infested with borers are planted. Each top may harbour one to five larvae of spotted borers at the time of planting. A plantation carelessly made in this respect will bring an infestation of at least 9,000 borers per arpent.

Out of 30,000 tops examined in an infested locality where planting was being done, 90 per cent. of the tops were found attacked. It is this state of affairs that has produced in certain localities of the island severe outbreaks of the spotted borer.

The method of killing the spotted borer *in situ* is of easy application. It consists in immersing the cane-tops in cold water for 72 hours, or in hot-water at 50–51°C.

for 2 to 2½ hours, or 52°C. for 30 minutes, or in saturated lime-water solution for 8 hours. The borer larvae are thus killed and the germination capacity is increased. With the cold water immersion process, it is recommended that cuttings should not be prepared from canes affected with leaf scald or gumming diseases. With varieties susceptible to these diseases, it would be preferable simply to select for planting tops free from borer damage.

Breeding of Parasites.

This method of control has not up to the present time been favourably considered by planters on account of the difficulties encountered in its application.

As parasites of the borers exist in Mauritius, it is necessary to warn planters against the practice of killing the borer larvae after their collection from cane stems on account of the possibility of their harbouring parasites. These larvae should be kept alive by placing them in bamboo tubes, or in other containers with portions of canes, so as to breed them, in order to obtain their parasites. They should afterwards be placed in breeding cages made of wooden cases on four feet and covered with tin, with one side consisting of wire gauze of 2 mm. mesh, which allows the adult parasites to come out but prevents any moths that may emerge from escaping.

Summary.

1. The first record of important damage due to borers in Mauritius dates from 1856, the species being the spotted borer, *Diatraea venosata*, Wlk. From 1856 to 1897, two other species of borers were introduced, the pink borer, *Sesamia vuleria*, Stoll, and the white borer, *Grapholita schistaceana*, Snell. From 1897 to 1916, the damage caused by these three borers decreased gradually, so that from 1916 to 1928 these pests were considered by planters as being of minor importance. From 1928 to 1932 an increase in the damage due to the spotted borer was observed nearly all over the island.

2. The spotted borer causes important damage on the coast belt during the dry and cold months, *i.e.*, April to July. The pink borer, distributed all over the island, causes damage of medium importance to young canes; it occurs with intensity during the wet and hot months of the year, *i.e.*, December to April. The white borer is also distributed nearly all over the island but causes damage of relatively slight importance in plantations, with the exception of very rare occasions when it occurs sporadically as a serious pest.

3. The losses due to the pink and white borers vary with the localities and are difficult to estimate. As an average, Rs.6.00 per arpent is incurred for control measures against these pests.

The spotted borer which attacks mature canes causes losses both in the field and in the factory. The reduction in the field, per arpent, averages 15 per cent. The loss in sugar averages 2.3 per cent., *i.e.*, 16 per cent. of sugar in cane. The gross loss per annum for the whole island is about 1½ million rupees, and the net loss approximately Rs.125,000.

4. The proportion of canes attacked by the spotted borer averages 30 per cent. From estimates made according to the method of Wolcott, in Porto Rico, it was found that the percentage of borers per 100 lb. of cane is 39, as a mean, and the number of borers per acre averages 15,698. The mean percentage of stems attacked by 1 to 5, 6 to 10, and 11 to 15 borers is of 87.6, 10.1 and 2.2 respectively. The proportion of nodes attacked varies between 10 and 25 per cent. approximately.

5. The cane varieties that are heavily attacked by the spotted borer are M.55, M.131, D.109, M.1474, White Tanna, B.H.10/12, R.P.6, D.K.74, D.130 and R.P.8.

6. The various methods of control used in the island for the last 15 to 20 years are discussed. Against the pink and white borers the use of trap plants is recommended as well as the collection of larvae. The burning of trash in the fields is to be avoided.

In the case of the spotted borer the destruction of larvae in the tops to be planted is recommended. A practical method consists in the immersion of the tops in cold water during 72 hours, or in hot water at 50–51°C. for 2 to 2½ hours, or 52°C. for 30 minutes, or in saturated lime-water for eight hours.

7. The breeding of the larval parasites is recommended on estates where larva collecting is practised.

8. The advantages or disadvantages of larva collecting and burning of trash are still under consideration.

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APPENDIX.
TABLE I.

Altitude feet	Spotted Borer (<i>Diatraea venosata</i>)			Pink Borer (<i>Sesamia vutieria</i>)		White Borer (<i>Grapholita schistaceana</i>)		Altitude feet
	Intensity of pest	Month	Season	Intensity of pest	Month	Season	Intensity of pest	
50	H	July-Nov.	Winter	L	July-Dec.	Summer	L	50
75	H	June	"	L	Dec.-April	"	V.L.	75
87	M	June	"	L	"	"	V.L.	87
100	H	June-Aug.	"	M	"	"	M	100
112	H	Mar.-April	"	L	"	"	M	112
150	M	Aug.-Sept.	"	M	Jan.-Feb.	"	V.L.	150
150	H	June-July	"	M	Dec.-April	"	V.L.	150
175	M	"	"	L	"	"	L	175
175	M	May-June	"	V.L.	"	"	L	175
200	M	"	"	V.L.	"	"	L	200
200	M	"	"	M	"	"	L	200
200	M	"	"	M	"	"	V.L.	200
250	H	June	"	M	"	"	V.L.	250
253	M	June-Aug.	"	M	Oct.-Dec.	"	V.L.	253
296	H	May-July	"	M	Dec.-March	"	M	296
296	H	June-Aug.	"	M	"	"	M	296
296	H	April-July	"	M	"	"	L	296
296	M	March-April	"	L	Dec.-April	"	L	296
300	M	"	"	M	"	"	L	300
300	H	June-Aug.	"	M	"	"	L	300
359	M	"	"	M	"	"	V.L.	359
400	M	"	"	V.L.	Dec.-July	"	V.L.	400
400	M	"	"	M	"	"	V.L.	400
400	M	"	"	M	"	"	V.L.	400
426	H	March-Aug.	"	M	Dec.-April	"	V.L.	426
450	M	April-July	"	M	"	"	V.L.	450
500	L	"	"	L	"	"	V.L.	500

TABLE I—(continued).

Altitude feet	Spotted Borer (<i>Diatraea venosata</i>)		Pink Borer (<i>Sesamia venteria</i>)		White Borer (<i>Grapholita schistaceana</i>)		Altitude feet
	Intensity of pest	Month	Season	Intensity of pest	Month	Season	
500	L	April-July	Winter	M	Dec.-April	Summer	500
600	L	"	"	H	"	"	600
625	L	June-July	"	M	"	"	625
700	L	"	"	M	Nov.-March	"	700
800	L	April-Sept.	"	L	Dec.-April	"	800
874	L	"	"	L	"	"	874
900	L	April-Aug.	"	M	"	"	900
995	L	"	"	M	Oct.-April	"	995
1000	L	April-July	"	M	Dec.-March	"	1000
1083	L	"	"	M	"	"	1083
1125*	M	April-June	"	M	"	"	1125*
1300*	M	"	"	M	Dec.-April	"	1300*
1300*	M	"	"	M	"	"	1300*
1300*	M	April-Aug.	"	M	"	"	1300*
1350*	L	April-July	"	M	"	"	1350*
1450	L	"	"	V.L.	"	"	1450
1575	L	"	"	L	"	"	1575

* At these altitudes various estates have been severely attacked by the Spotted Borer for the last four years.

H = High infection.

M = Mean infection.

L = Low infection.

V.L. = Very low infection.

S = Sporadically.

TABLE II.

Altitude feet	Varieties	Borers % lbs. canes : mean of localities	Borers per arpent : mean	Percentage of canes attacked by		
				1 to 5 borers	6 to 10 borers	11 to 15 borers
1-100	DK.74	51.0	20,400	87.5	8.7	3.7
101-200	"	31.2	12,490	90.4	9.6	0.0
401-500	"	37.0	14,800	88.8	11.2	0.0
1101-1200	"	4.0	1,600	100.0	0.0	0.0
1201-1300	"	42.0	16,800	78.9	15.7	5.3
1501-1600	"	20.0	8,000	100.0	0.0	0.0
1-100	M.131	49.0	19,600	76.6	13.9	9.3
101-200	"	42.6	17,050	—	—	—
1-100	White Tanna	88.2	35,280	97.5	2.5	0.0
101-200	" "	18.4	7,370	91.1	6.6	2.2
201-300	" "	15.0	6,000	90.9	9.1	0.0
401-500	" "	62.5	25,000	70.9	25.3	3.6
701-800	" "	58.0	23,200	62.5	12.5	25.0
801-900	" "	37.9	15,160	80.9	14.2	4.7
1101-1200	" "	5.0	2,000	100.0	0.0	0.0
1201-1300	" "	23.8	9,566	90.1	8.4	1.4
1301-1400	" "	44.0	17,600	81.8	9.1	9.1
1501-1600	" "	31.0	12,400	77.7	22.2	0.0
1-100	D.109	51.0	20,400	100.0	0.0	0.0
101-200	"	88.8	35,506	100.0	0.0	0.0
201-300	"	63.5	25,400	100.0	0.0	0.0
101-200	M.252	29.0	11,600	100.0	0.0	0.0
101-200	M.55	38.0	15,200	80.0	20.0	0.0
201-300	"	43.0	17,200	84.6	15.4	0.0
701-800	"	37.0	14,800	62.4	37.4	0.0
1101-1200	"	4.0	1,600	100.0	0.0	0.0
1201-1300	"	40.1	16,040	91.3	7.0	1.5
1201-1300	R.P.6	47.1	18,840	84.6	12.8	2.5
1-100	R.P.8	58.0	23,200	93.7	6.2	0.0
101-200	"	50.0	20,000	63.6	36.3	0.0
1201-1300	Striped Tanna	22.9	9,160	90.4	9.5	0.0
1201-1300	Uba	30.2	12,080	96.4	3.5	0.0
1201-1300	Cannes de graines	31.7	12,680	91.9	7.0	1.0
General mean		39.2	15,698	87.6	10.1	2.2

TABLE III.

	White Tanna*		White Tanna*		M.55*	
	Healthy canes	Attacked canes	Healthy canes	Attacked canes	Healthy canes	Attacked canes
Density	1077·8	1071·8	1083·1	1064·9	1073·2	1063·0
Vivien	20·8	19·2	22·2	22·7	19·6	16·9
Sucrose % cc. ...	17·5	15·9	19·98	17·78	17·04	14·4
Purity	84·1	82·9	90·0	78·8	87·0	85·2
Glucose % cc. ...	1·11	1·22	0·32	0·38	0·3	0·39
Glucose ratio ...	6·35	6·69	1·6	2·1	1·7	2·3
Sucrose % canes ...	14·69	12·48	15·5	13·1	12·7	10·6
Loss of sucrose % canes	2·21		2·4		2·1	

* Analysis made on 300 lb. cane.

EXPLANATION OF PLATE II.

- Fig. 1. *Diatraea venosata*, Wlk. Larva $\times 3$
 „ 2. „ „ „ Eggs $\times 6$
 „ 3. *Sesamia vutieria*, Stoll. Larva $\times 3$
 „ 4. „ „ „ Eggs $\times 6$
 „ 5. Portion of cane stem attacked by *Diatraea* showing the exit holes of the larva on right and a section of the tunnel (left). (Natural size.)
 „ 6. *Diatraea venosata*, Wlk. Adult $\times 2$
 „ 7. *Sesamia vutieria*, Stoll. „ $\times 2$



1



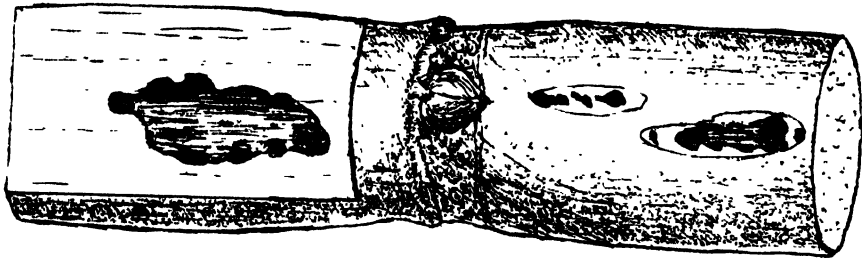
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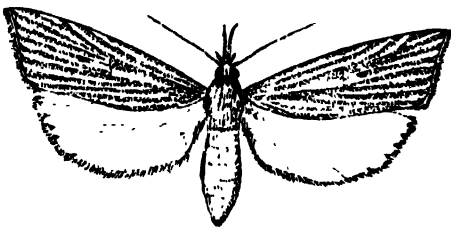
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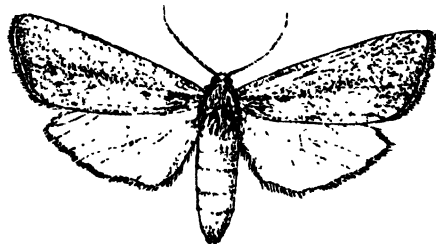
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7

STUDIES OF THE WILLOW-SHOOT MOTH, *DEPRESSARIA CONTERMINELLA*, ZELL.

By MARY MILES, M.Sc., *Buckle Research Scholar*, and
HERBERT W. MILES, M.Sc., Ph.D., *Adviser in Agricultural Entomology*.

(*Contribution from Victoria University of Manchester.*)

(PLATE III.)

I. BIOLOGY OF *DEPRESSARIA CONTERMINELLA*.

By MARY MILES.

Field observations in Lancashire and Cheshire indicated that *Depressaria conterminella*, Zell., was of considerable economic importance in commercial beds of *Salix viminalis*, and the presence of the insects in the crops has led to inquiries for control measures. Little information was available concerning the biology of the moth;* therefore, at the suggestion of Dr. H. W. Miles, Adviser in Agricultural Entomology for the North-West Province, a study was made of the life-history and habits of *D. conterminella*, field observations being supplemented by observations in the laboratory.

The injury caused by *D. conterminella* is well known to willow growers. The larvae feed singly in the tips of the willow rods during spring and early summer, and their habit of spinning the leaves together about the terminal bud renders their presence obvious. In the course of feeding the larvae destroy the terminal bud. Subsequently lateral shoots develop and the condition known as "bushy top" is produced. Attacked rods fail to attain their full length and are of little value commercially.

Attack by *D. conterminella* seems mainly confined to *S. viminalis* though occasionally larvae are found in the shoots of *S. purpurea*. At Mawdesley, Lancashire, in 1933 beds of *S. purpurea* adjacent to beds of *S. viminalis* became infested with larvae of *D. conterminella* and some injury to the crop was apparent. Generally, however, the insect may be abundant on *S. viminalis* and almost entirely absent from adjoining beds of *S. purpurea*.

Description and Life-history.

The Egg Stage.

Newly emerged moths were confined on small willow stocks growing in pots and later the stocks were examined for eggs. The eggs are difficult to find. They are secreted in crevices in the bark of the stocks near the level of the soil, frequently between the bark and the woody tissue on the cut surfaces of shoots of a previous year. At first the eggs are translucent white but later they become dark reddish brown and remain this colour until hatching. They are broadly oval and measure 0.6 mm. in length. The chorion is sculptured with broken longitudinal ridges. A number of eggs are laid on the stock, for though the writer has never found more than three, as many as 18 first instar larvae have been found on a single stock brought into the laboratory just before hatching began.

* Insect Pests and Fungus Diseases of Basket Willows.—Bull. no. 29, 1931, Min. Agric. & Fish.

The eggs are laid during June and July and hatch in the following spring. In 1932 eggs hatched about the middle of April, and first instar larvae were taken in the plantation on April 18th. In 1933 the season was earlier and eggs hatched about the first week of April, so that by 10th April, the date of the first visit to the plantation, first instar larvae were fairly numerous in the buds. Observations in 1932 and 1933 indicated that the time of hatching of *D. conterminella* was associated with the time of opening of the willow buds. Almost as soon as the leaf-buds showed green tips the tiny larvae of *D. conterminella* were found feeding within them. It is probable, however, that hatching occurs over some period, since it is usual to find larvae of three consecutive instars feeding in the plantation at the same time, and larvae continue to be found about the bushes a fortnight or so after the main brood has entered the soil for pupation.

The Larval Stage.

Newly enclosed larvae of *D. conterminella* are active and wander in search of food. In beds where the rods are left during the winter, buds open first at the tips of the shoots and the larvae travel six or eight feet before settling down to feed. Where the rods are harvested before the eggs hatch, the larvae find opening buds at the base of the plants.

First instar larvae penetrate directly to the interior of the buds by tunnelling through the downy, rather fleshy young leaves, leaving particles of yellowish frass around the entrance holes. In the later stages the larvae crawl between the outer leaves at the tips of the shoots, spinning them together with silk (Plate III, fig. 1). In the shelter thus formed the larvae eat out the terminal bud, leaving a tunnel about an inch long, filled with frass. Ecdysis takes place within a slight cocoon in the feeding site.

The larvae have four instars. In the first three instars the larvae are greyish green with the head, tergites of the prothorax and tenth abdominal segment, thoracic legs and setal bases black (Plate III, fig. 2). After the third ecdysis there is a marked change in colour. The larvae (Plate III, fig. 3) become yellowish green with the head and legs pale greenish. The head bears two pairs of dark areas, one pair rather crescent-shaped and containing some of the eyes, and the second pair behind the first on the lateral margin of the head. The bases of the setae are no longer distinct but the spiracles appear as a lateral row of brownish spots. Some fourth instar larvae appeared intermediate between the two forms, there being some clouding on the head laterally, on the margin of the prothoracic plate and about the bases of the setae; but these intermediate colour forms were readily distinguished from larvae in the third instar by the yellowish head and yellowish green body. Prior to the change in colour the larvae measure up to 9 mm. and in the final instar they measure up to 12 mm.

The time spent in the various instars appears to vary with temperature conditions. In the laboratory, where the temperature was 58–61°F. during the day, and rarely fell below 54°F. during the night, the larvae spent 7–10 days in each of the first three instars and 5–7 days feeding in the final stage. Observations out of doors indicated that under normal conditions the duration of each instar was probably 10–14 days. In the laboratory, larvae matured in rather less than five weeks, but under natural conditions they required six weeks to reach maturity. In 1932 when eggs of *D. conterminella* hatched about the middle of April, larvae in the final instar were collected on 26th May, and in 1933, when the eggs hatched at the beginning of April, mature larvae were collected on 17th May.

It was observed that when larvae in captivity exhausted the food supply in one shoot they travelled to another, and it was estimated that in the course of feeding each larva destroyed 3–4 shoots. In the plantation injury caused by the larvae early in the season is not readily apparent. The crop grows so rapidly that buds destroyed before any growth is made and shoots killed when under three inches in length are

soon hidden. It is only in the later stages of attack when the rods attain a length of 1-3 feet that the injury is apparent in the plantation. When infestation is severe, over half of the rods may be rendered valueless by the destruction of their growing points.

The Pupal Stage.

Pupation takes place in the soil. The larvae construct silken cocoons, to which the soil adheres, usually below the surface of the soil but occasionally, in captivity, under dead leaves. The adults emerge about three weeks after the larvae enter the soil.

Larvae confined in tubes for observation constructed cocoons between leaves or between a leaf and the glass. After cocooning they remained inactive for 3-4 days, during which they contracted and became dense whitish green. After ecdysis the pupa was pale greenish, but it rapidly hardened and darkened to brown with traces of green coloration under the wings. The pupa is short and plump, 8 mm. in length and 3 mm. across the broadest part. The wings and antennae extend to the caudal margin of the 4th abdominal segment and segments 5-10 are movable. The margins of the segments are well defined, the chitin forming a ridge between the edges of the segments and the intersegmental membrane. The spiracles on segments 2-8 of the abdomen appear slightly raised and the pupal sex characters are distinct. The cremaster consists of a small protuberance at the tip of the 10th segment, bearing about eight hooked spines.

In insects under observation the pupal stage lasted 17-19 days. Taking into consideration the 3-4 days spent as a larva in the cocoon, this period corresponds with the pupation period of three weeks normally spent in the soil.

The Adult Stage (Plate III, fig. 4).

Moths bred from larvae collected in the willow plantations were identified as *Depressaria conterminella*, Zell. The moth has been described by Meyrick (Revised Handbook of British Lepidoptera, 1928). It measures 17-19 mm. across the outspread wings. The forewings are crimson fuscous suffused with pale yellowish and dark brown scales. The base of the wing is yellowish and extensively marked with black. About a third of the distance along the wing is a small curved dark area, margined with reddish scales and followed by a pale yellowish area. The crimson colouring is most intense in the apical third of the wing. It is present along the costal and anal margins and suffuses the alternating light and dark lines running parallel with the veins to the apical margin. The hind wings are whitish fuscous.

The moths are on the wing in June and July. In captivity they spent the day on the surface of the soil and about the willow stocks, where their colouring rendered them inconspicuous. They were not easily disturbed, and when forced to take flight they quickly settled again on the soil or stock. Neither mating nor oviposition were observed. Moths in captivity lived 8-12 days. Adults were only occasionally taken in the plantation, probably because of their habit of resting near the ground during the day. It is interesting to note that although larvae of *Depressaria conterminella* have been reared to maturity for three consecutive seasons no parasites have been found.

Other Lepidoptera causing similar Injury.

Observations showed that in addition to *D. conterminella* other Lepidoptera were responsible for injury to the tips of the willow rods. During this investigation *D. conterminella* was the only species present in sufficiently large numbers to be considered of economic importance, but other species may be regarded as potentially injurious.

In 1931 larvae of *Depressaria ocellana*, F., were found feeding in the shoots of *S. purpurea*, and a moth of this species emerged from a cocoon collected from *S. viminalis*. The larvae were collected on 15th August and appeared fully grown at the time of collection, indicating that this species reached maturity 2-3 months later than *D. conterminella*. Mature larvae of *D. ocellana* measured about 18 mm. and had the head pale yellowish green, the body deeper green with three longitudinal bands of darker green along the dorsum and setae arising from small black chitinous bases. As in the case of *D. conterminella*, the larvae feed in the tips of the shoots and spin the leaves together. In the course of feeding the stem was severed just below the terminal bud. In captivity the larvae pupated in the feeding site, and this is probably normal for the species, since a pupa was collected from the tip of an injured shoot. Moths emerged from 31st August to 19th September.

The following species of Lepidoptera were found in shoots of *S. viminalis*. The larvae fed in the tips of the shoots and produced injury similar to that caused by *D. conterminella* but it was not ascertained if the tips of the shoots were killed.

Larvae of *Cheimatobia brumata*, L., were abundant in beds of *S. viminalis* during May and June. Numbers of the larvae fed openly on the leaves but in the early part of the season larvae were common in the tips of the shoots.

Larvae of *Orthosia lota*, Cl., were numerous in the willow beds at Mawdesley. These larvae generally fed in whitish cocoons in the tips of the shoots, but the cocoons also occurred between leaves lower down the rods.

Larvae of several species of Tortricid moths were found feeding in the tips of the willow shoots. These larvae seemed dark greyish green, with the head, thoracic legs, thoracic and caudal sclerites black and black areas at the bases of the setae. They were more active when disturbed than larvae of *D. conterminella* and pupated in the injured shoots. Tortricids from the tips of shoots of *S. viminalis* included *Pandemis corylana*, F., *P. heparana*, Schiff., *P. cinnamomeana*, Tr., *Peronea hastiana*, L., *Argyroplote micana*, Frol., and *Cnephasia pascuana*, Hübn. In 1931 *C. pascuana* and *C. chrysanthemana*, Dup., were collected from the tips of the shoots of *S. viminalis*, and it seems possible that these species, though usually associated with Compositae, feed occasionally in the tips of the shoots of cultivated willows.

Dwarf willows were examined at Formby, Lancashire, for larvae of *D. conterminella*. This species did not occur, but the tips of the shoots were badly infested with larvae of *Anacampsis populella*, Cl., *Compsolechia temerella*, Zell., and *Gelechia sororculella*, Hübn. In captivity the species from dwarf willow fed readily on cultivated willows.

The writer gratefully acknowledges the assistance of Mr. H. Britten and Mr. H. W. Daltry in the determination of the species collected and expresses thanks to Dr. H. W. Miles for the photographs illustrating the paper.

ON THE CONTROL OF *DEPRESSARIA CONTERMINELLA*, ZELL.

By HERBERT W. MILES.

Observations described in the previous section showed that *D. conterminella* overwintered in the egg stage on the willow stocks. This suggested that it might be possible to control the insect by some winter treatment of the stocks aiming at the destruction of the eggs. It was also observed that buds at the tips of the shoots developed first and were infested first by larvae, and that development was earlier on uncut stocks than on stocks cut during the dormant season. This indicated the possibility of supplementing winter control measures by some modification of the procedure of harvesting, so that newly emerged larvae were removed with the crop or starved before the development of basal shoots.

Control by the Destruction of Eggs.

Paraffin emulsion and 7 per cent. tar distillate emulsion were used as winter sprays against *D. conterminella* without success, probably owing to the difficulty of thoroughly wetting all parts of the stocks with spray from the horse-drawn sprayer used on the holding. This method of control was expensive in relation to the value of the crop, and though there is little doubt that these sprays would have given some control under other circumstances, the cost of spraying rendered this method unsuitable.

In East Anglia a method of burning has been used with some success against *Acalla comariana*, Z., a Tortricid moth infesting strawberries and overwintering in the egg stage on the low-growing host-plant. It was decided to use a similar method against *D. conterminella* on willows.

After the willow crop had been removed, a rick of worthless hay was distributed down the rows of willows and drawn well over the stocks in the dry weather at the end of February 1932. The hay was then set on fire and the slight breeze carried the flames down the rows. The heat generated was sufficient to destroy all green herbage and saplings of other trees growing here and there in the rows, and the buds of a neighbouring hawthorn hedge were injured. The moss was burnt off the willow stocks and in some cases the heat discoloured and even damaged the bark of the stocks. As a result of the burning, growth was delayed for some time.

Representative treated and untreated stocks were placed in pots and taken into the laboratory to force the growth. Shoots appeared on the untreated stocks towards the end of March and became heavily infested with larvae of *D. conterminella*. Growth was rather later on the treated stocks, but when shoots were produced they were free from infestation. In the plantation growth was about a week later on the burnt stocks, but by the end of May they were growing vigorously and no differences in growth could be seen between the treated and untreated plots. On 27th June the plots were examined and the following data obtained.

TABLE I.

Field	Plot	Treatment	No. of stocks	Infested shoots	Total shoots	Percentage infested shoots
A	1	Burnt Control	50	43	683	6.4
	2		50	273	747	36.5
B	1	Burnt Control	50	59	721	8.1
	2		50	267	785	34.0

The table shows that burning over the crop reduced infestation by *D. conterminella* from 36 per cent. to 6 per cent. in one field and from 34 per cent. to 8 per cent. in another. The treatment appeared to influence the yield by reducing the number of shoots produced by the stocks, but the increase in the number of straight rods in the treated plots increased the value of the sample and more than compensated for the lighter crop.

Control by Delayed Cutting.

In order to show the influence of late cutting on infestation by larvae of *D. conterminella*, four representative plots on the willow beds at Mawdesley were harvested on different dates from 20th April to 8th May and observations made

on the degree of infestation of the subsequent crop. In the Mawdesley district it is the usual practice for growers to cut and clear the willow crop during the period December to March, so that to delay cutting until the latter part of April and the beginning of May was a distinct departure from the normal routine. By the end of the first week of May the young shoots at the tips of the previous year's rods were 2-3 inches in length and growth was well started on stocks cut at the usual period. At this time heavy infestation was apparent at the tips of the uncut rods and in the shoots developing where the crop had been cut. The late-harvested plots were examined on 25th June and data obtained on the incidence of attack are given in the following table.

TABLE II.

Date of cutting	Plot	No. of stocks examined	Infested shoots	Total shoots	Percentage of infestation
20.iv.31	1	50	349	801	43.5
27.iv.31	2	50	209	756	27.6
4.v.31	3	50	57	853	6.6
8.v.31	4	50	26	878	2.9

The value of late cutting in reducing attack by *Depressaria conterminella* is readily apparent from the table, since by delaying cutting until the end of the first week of May infestation was reduced from over 40 per cent. to under 5 per cent. This method of control has an important consideration to recommend it. Cutting is a routine operation, and to delay cutting until it is likely to reduce infestation involves little extra cost other than the slight seasonal rise in the cost of labour. Late cutting appeared to have no adverse influence on the numbers of shoots produced, but it curtailed the growing season for the subsequent crop. This is of considerable importance to willow-growers. It was estimated that the weight of the crop was 15-20 per cent. less on the latest cut plot than on the earliest. This loss in weight was offset, however, by the marked improvement in quality, the absence of "bushy top" in the crop resulting in a higher price being paid for the rods.

Conclusions.

With small acreages of willows infestation by *Depressaria conterminella* can be effectively checked by the late harvesting of the crop. The actual date for harvesting depends on the season. In Lancashire the willow buds open about the middle of April in a normal season, and infestation by larvae of *D. conterminella* is well developed about 10 days later. Cutting the crop 7-14 days after the buds open should remove many of the larvae and numbers of those hatching later are likely to starve before the development of the new growth at the base of the plants.

With extensive willow beds this method of control presents some difficulty, since only part of the crop could be handled in the period suggested. Infestation on large acreages could be reduced by rotating the method of late cutting so that each part was cut late once in the course of several years, and adopting supplementary control measures aiming at the destruction of the overwintering eggs. Experiments in 1932 indicated that burning over the cut stocks with waste hay, straw or rubbish was a cheap and effective means of checking the pest during the dormant season.

Summary.

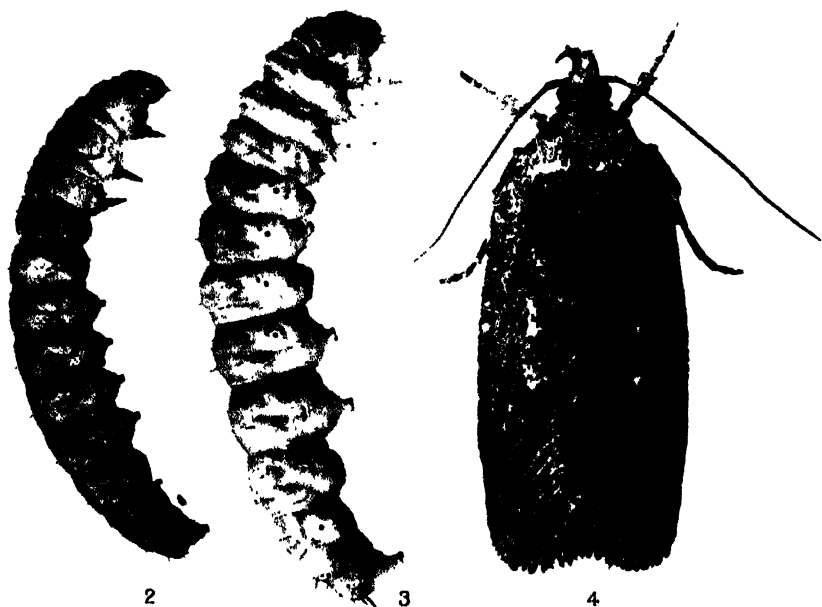
A study has been made of the biology of *Depressaria conterminella*, Zell., the most important willow-shoot moth occurring in commercial willow beds of Lancashire and Cheshire.

The eggs are laid in June-July in bark crevices on the stocks near the level of the soil. Hatching takes place in the following spring, beginning about the time the buds open. The eggs are described.

On hatching the larvae travel to the opening buds. First instar larvae tunnel through the outer leaves into the buds, but larvae in the later stages crawl between the leaves, spinning them together to form a feeding shelter. Larvae have four instars and at the third ecdysis there is a marked colour change. Both larval forms are described. In the course of feeding each larva destroys 3-4 shoots. Infested shoots are illustrated. Pupation takes place in the soil and adults emerge after about three weeks.

The habits of the moths are described. The species is univoltine and no instance of parasitism has so far been observed. A list of other Lepidoptera bred from the shoots of willows is given.

The nature of the crop does not permit of costly control measures. The study of the biology suggested that infestation might be checked by delaying harvesting until after the larvae hatched. In an experiment in the field it was found possible to reduce infestation from over 40 per cent. to under 5 per cent. by this method. Infestation was also reduced by burning waste hay over the rows of willow stocks during the dormant season.



John Innes Hort. & Nurseries Ltd. London

1. Shoots of *Salix viminalis* infested by larvae of *Depressaria conterminella*; 2. Third instar larva ($\times 8$), 3. Fourth instar larva ($\times 8$), 4. Adult ($\times 8$).

ON THE BIONOMICS OF A EULOPHID (*TRICHOSPILUS PUPIVORA*, FERR.) A NATURAL ENEMY OF THE COCONUT CATERPILLAR (*NEPHANTIS SERINOPA*, MEYR.) IN SOUTH INDIA.

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Introduction.

The black-headed palm caterpillar (*Nephantis serinopa*, Meyr.) has been known to be a serious pest of coconut palms both in Ceylon and South India for many years past, and during the past ten years its appearance on a serious scale along the Malabar coast in South India has been attracting the attention of the Entomological Section of the Madras Agricultural Department. Among the different methods of control, the utilisation of the natural enemies of the pest has been tried to some extent. One of the more important natural enemies found to exert some appreciable influence on this pest was a Eulophid wasp, *Trichospilus pupivora*, Ferr. As one of the officers of the Entomological Section engaged in the work connected with this coconut pest, the author had opportunities of closely studying this parasite, and in this paper a brief account is attempted of the bionomics of this insect and of some methods employed in breeding it on a large scale.

1. The Parasite.

This insect was first noted as a pupal parasite of the coconut caterpillar in Cochin on the Malabar coast in October 1925, and it has since been described by Dr. Ferrière (Bull. Ent. Res. **21** 1930 p. 358).

The adult insect is a tiny brown creature with delicate, small, transparent wings folded over the rounded abdomen. While the average size is, as described by Ferrière, 1.0–1.2 mm., specimens measuring 1.5–2 mm. have been noted. The insect is very active and occurs abundantly in nature in several parts of Malabar during the monsoon months, being easily distributed to a distance by flight or by wind. In the field, the presence of the parasite is easily noticed by the characteristic black colour of the host pupa, which often harbours 100–300 developing parasites.

The sexes.

In external features there is not much difference between the male and female, but in the latter the abdomen is rounded and slightly flat with a median ventral streak, while in the male it is slightly oval and pointed posteriorly. Only on two occasions was the union of the sexes observed, and that immediately on emergence from the host. The males are usually smaller and always fewer than the females, and one male appears to fertilise a large number of females even while within the host pupa before emergence. This is believed to be so in view of the facts that the sexes are seldom found in copulation after emergence, that unfertilised females do not parasitise a fresh host, and that the parasites that emerge in a natural way attack host pupae without exception.

The life-history.

The eggs are very minute objects, hardly visible to the naked eye as transparent streaks in the milky fluid contents of the *Nephantis* pupa. The egg is roughly oval in shape, rounded at one end and bluntly tapering at the other, measuring 0.2 mm. by 0.06 mm. In about 24 hours the eggs hatch, and the grubs begin to feed on the contents of the pupa. In 5 to 7 days after the eggs are laid, the grubs are full-grown

and have devoured the whole contents of the host. The full-grown grub, devoid of any appendages, measures 2 mm. by 0.6 mm. and forms a naked pupa covered only by a very thin transparent membrane. In about 5 to 6 days after pupation the compound eyes and the 3 ocelli become bright red, the antennae are clearly marked, and the abdominal ventral streak of the female is faintly visible. In about 8 to 10 days after pupation the parasites, which are closely packed within the pupal case of the host, become adults and emerge by biting tiny holes in the now brittle pupal cell. The whole life-cycle is completed in the course of 16 to 17 days under favourable conditions, but the period varies according to the weather, extending to 20 days during wet weather in June or being reduced to about 15 days during the hot dry weather of March-April. The parasite has been bred all through the year uninterruptedly in the laboratory and found to complete 22 generations during a period from 5.vi.1928 to 7.vi.1929 at the parasite breeding station at Calicut, in Malabar, the life-cycle taking 15-20 days, with an average of 16.5 days.

TABLE I.
Egg-laying Capacity and Longevity of the Adult Parasite.

Adult life in days	No. of pupae attacked	No. of parasites produced	Average no. in one pupa	Average no. produced by one parasite
5	10	464	46	232
5	7	330	47	165
4	5	292	58	146
3	2	92	46	92
4	4	143	35	143
4	1	45	45	45
9	5	236	47	236
7	7	177	25	177
5	5	215	43	215
7	2	148	74	148
4	3	125	41	125
4	1	46	46	46
3	1	132	132	132
4	2	173	86	173
4	3	181	60	90
4	4	247	61	123

The adult parasites have lived for 7 days after emergence, but they remain alive for fewer days during hot, dry weather; feeding them with sugar solution, yeast or dilute honey has not had the effect of increasing their longevity. In nature the parasite has been observed to perch on a pupating caterpillar after the latter has spun its cocoon and is resting prior to pupation. Under laboratory conditions such pupating caterpillars were supplied, and the parasite has lived up to 9 days in one instance, laying eggs in five pupae (Table I).

Alternate hosts of the insect.

In the field the parasite was once recorded at Calicut (Malabar) in the pupae of the cotton leaf-roller (*Sylepta derogata*, F.). In the laboratory the parasite has been successfully reared on the pupae of the following : *Spodoptera mauritia*, Boisd. (paddy army-worm); *Prodenia litura*, Fabr. (tobacco cutworm); *Acontia graellsii*, Feist. (cotton semilooper); *Cnaphalocrocis medinalis*, Gn. (paddy leafroller); a *Pyralid* on grape-vine; *Ergolis merione*, Cr. (castor butterfly); and a Hesperiid coconut caterpillar.

2. Artificial Breeding of the Parasite in Bulk.*Breeding technique.*

The parasite is easily reared in the laboratory in large numbers, under favourable weather conditions, provided that suitable host material is made available. Ordinary glass specimen tubes 6 in. by 1 in. with bored corks, the holes of which are closed with 90-mesh wire gauze, will form suitable breeding-cages. Into each cage 5-6 of the fresh *Nephantis* pupae can be introduced, with 5-10 parasites. The parasites are easily transferred from tube to tube, as they march towards light in streams. The tiny creatures, as soon as introduced, halt on the pupae and begin to lay eggs in the course of 2-6 hours, exercising little or no choice as to the part of the pupa in which the egg is laid, and die in 2-6 days after oviposition. The cages are cleared of all dead parasites and unhealthy host pupae, if any, and in the course of about 6 days the attacked pupae begin to show the characteristic sickly dark colour. The parasites usually emerge in 16-18 days; they are then exceedingly active and crowd towards the lighted part of the cage.

In the laboratory, during certain parts of the year, the parasitised pupae become subject to fungus and bacterial attacks, and thus a considerable number of host pupae are destroyed along with the developing parasites inside. The condensation of moisture favours the growth and multiplication of these micro-organisms. By systematically cleaning the cages and pupae, using clean muslin and camels' hair brushes, and by sterilising the tubes and corks in boiling water or steam before use, the growth of fungi and bacteria can be avoided to a great extent, and a large number of parasites can be reared successfully. On an average, it was found possible to breed not less than 10,000 parasites a month in the laboratory at Calicut by this method.

Influence of weather in nature and in laboratory.

These delicately built parasites are, however, very susceptible to weather changes. While the parasite is at its best during the wet weather, it practically disappears from the field during the hot dry season. In the laboratory, too, during hot dry weather the host pupae themselves dry up, killing all the contained parasites. The egg-laying capacity of the parasite is also much reduced; the few developing parasites are smaller in size for want of nutriment, and the parasites themselves do not live to lay eggs for more than a day or two. During the dry months of March to May, tubes containing parasites under rearing were placed in a specially constructed breeding chamber, in which conditions of lower temperature and higher humidity were maintained by means of an ice pack.

This breeding chamber (fig. 1) consists of a zinc box of three compartments fitted with perforated shelves, with a common space beneath containing water, the zinc box itself, surrounded by ice and saw dust, being contained in a larger wooden case. A large number of cages under observation were placed in the chamber, and at the same time "controls" were also kept under ordinary laboratory conditions. The temperature and relative humidity both in the laboratory and in

the breeding chamber were recorded. The results of these experiments were examined with regard to the following points :—(1) The number of adults emerging from individual parasitised pupae ; (2) the duration of the period of development ; (3) the condition of the adult emerging ; and (4) the relative number of cases of failure.

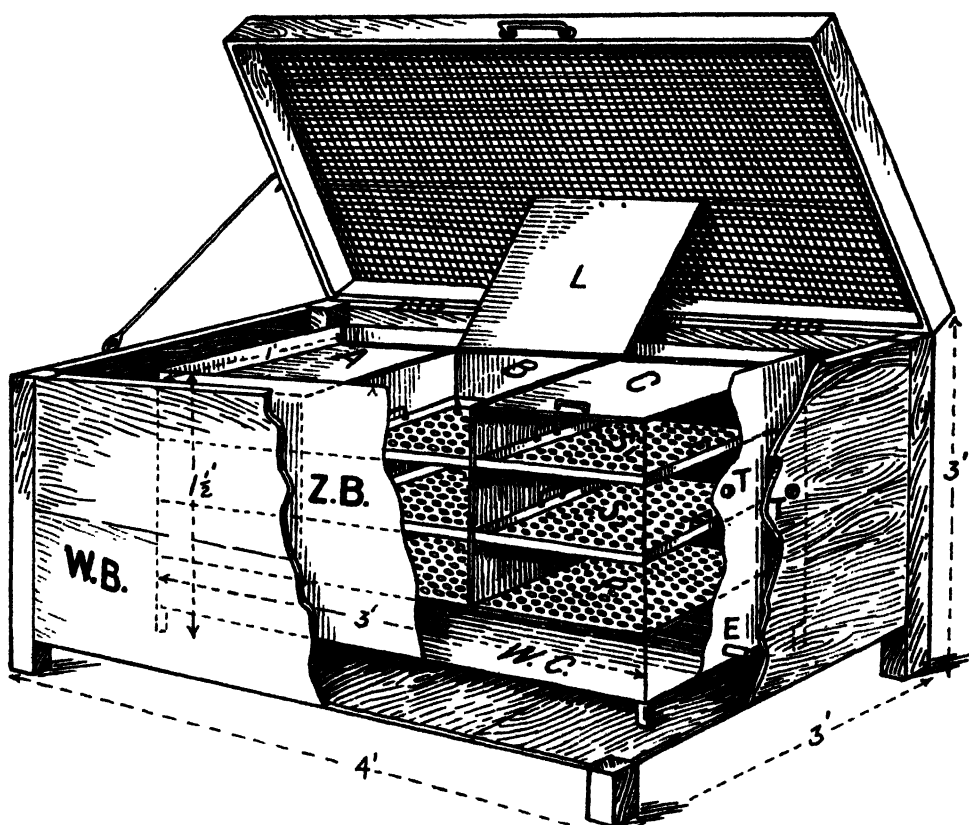


Fig. 1. Moist chamber for rearing parasites: W.B., wooden box; Z.B., zinc box inside the wooden box; A.B.C., three compartments; S1, S2, perforated shelves (removable); P, perforated bottom; W.C., common water space at bottom of compartments; T, holes for inserting a thermometer from outside; E, outlet for water; L, covering lid of compartment B.

The experiments, though not exhaustive, indicate the probable influence of weather and suggest a means of continued rearing of the parasite in the laboratory during the prevalence of adverse climatic conditions. From the data obtained the following observations were made :—(1) A temperature of 78°F.-82°F. and relative humidity 92-94 appear to be favourable conditions for the parasites ; (2) though a high temperature such as 85°F. has the effect of accelerating the development, it results in killing many of the grubs for want of nutriment. In such cases, even if a few specimens managed to reach the adult stage, they were noted to be weak and undersized. On the other hand, more humid conditions induced the growth of fungi and bacteria, which destroyed the parasitised pupae or prevented the wasps that developed inside from emerging, possibly because the wet conditions made the pupal skin too tough and leathery for them to bite their way out. In such cases of delayed emergence, exposure to the sun for a short time enabled the parasites

to come out normally. In short, the parasites die within the host pupae under hot dry weather conditions as well as under very humid conditions. In both cases, if the parasites are let out by artificial puncture of the host pupa, they are mostly unfertilised, though fully developed, and do not parasitise fresh pupae.

In a large number of cases the parasites were individually separated into cages during their pupal stage, and when each one became adult and active, fresh host pupae were supplied; but in none of these cases were the pupae parasitised, whereas those in lots with chances for mating behaved normally.

3. The Potentiality of the Wasp as a Parasite.

As determined from the number of adult parasites emerging from the attacked pupae it was found that (a) the parasite lays on an average 55 eggs in each pupa; (b) one parasite lays about 100-200 eggs; (c) the parasite attacks more than one pupa; and that (d) more than one parasite lays its eggs in one and the same pupa (Table I). Under laboratory conditions the parasite has attacked pupae even 7-8 days old, as shown in Table II.

TABLE II.
Ages of parasitised Host Pupae.

Date of pupation of host caterpillar	No. of cages set	Date of parasite introduction	Date of emergence of parasites	Average no. of adults per pupa	Age of pupa supplied
6.xi.29	4	6.xi.29	23.xi.29	140	Same day
6.xi.29	3	7.xi.29	24.xi.29	211	2nd day
6.xi.29	3	8.xi.29	25.xi.29	201	3rd ..
30.v.29	2	2.vi.29	22.vi.29	112	4th ..
12.vi.29	2	16.vi.29	5.vii.29	175	5th ..
29.vi.29	2	4.vii.29	23.vii.29	143	6th ..
29.vi.29	4	5.vii.29	24.vii.29	88	7th ..
29.vi.29	2	6.vii.29	25.vii.29	57	8th ..
29.vi.29	4	7.vii.29	Not parasitised		

Remarks :—5-10 parasites were let in for each cage. The pupal period of the host is 11-12 days.

The parasite flourishes in large numbers in the field during and immediately after the rains from July to February, but becomes rapidly reduced in numbers during the hot dry weather from March to May, when the host in the pupal stage is also not present in large numbers (Table III). In a particular area, when the parasites are released, according to the availability of the food material they multiply rapidly, especially in the tracts where the caterpillar infestation is old and several generations of the pest overlap. During adverse weather, the liberated parasites attack a good proportion of the then existing pupae in the field and prevent the emergence of moths, even though they themselves are not able to multiply further. For close observation, samples of infested fronds were collected each month from a reserve area, where parasites were being liberated. Two bundles of 100 leaflets each were taken, and the *Nephantis* pupae counted. Of these pupae, the parasitised ones were sorted out and recorded after a week's observation or more, and the average

per 100 leaflets recorded. It was seen (Table III) that (1) the parasite at its best could destroy 75 per cent. of the existing pest population in the pupal stage; (2) live parasites in adult form were practically absent during the period from March to May when the host pupae were also few; and that (3) there always exist in the field some pupae inaccessible to the parasites.

From the point of view of (1) its exceedingly prolific nature; (2) its capacity to attack more than one host pupa; (3) its eminent suitability to laboratory rearing; (4) its delicately built structure and active habits for easy and distant dispersal (it has been recorded 3 miles away from the place of introduction); (5) absence of hyperparasites, this parasite is one of the best of its kind to bring about control of the pest in large areas. Repeated introduction of the parasite in bulk into selected areas has had the effect of appreciable control of the caterpillar pest in 16-24 months. But unfortunately the Eulophid is unable to thrive during the hot weather, which is just the period when the pest gets the upper hand, and thus leaves ample chance for the latter to spread to new areas whither the parasites are slow to follow under natural conditions.

TABLE III.
Degree of Parasitisation in the Field during different Months.

Months	No. of pupae per 100 leaflets	No. of pupae parasitised	Percentage of pupae attacked	Remarks
June 1930	32	14	43.7	The counts were taken from an infested reserve area where parasites were released month by month, and thus parasitised pupae were not totally absent in any month, even at the time when pupae were very few in the field.
July "	47	29	61.7	
August "	67	24	35.8	
September "	46	22	47.8	
October "	52	39	75.0	
November "	39	29	74.6	
December "	56	40	71.4	
January 1931	29	15	51.7	
February "	20	15	75.0	
March "	12	8*	66.6	
April "	15	6*	40.0	
May "	21	8*	38.0	

* Live parasites were very few and sometimes dried up dead grubs were also noted.

Though the mechanical method of pruning and burning the infested fronds does much to prevent the spread of the pest, the ultimate control in any one area is believed to be mainly due to natural enemies and climatic factors; and in the opinion of the author the Eulophid parasite described in this paper is responsible in no small measure for keeping the caterpillar pest under control.

In conclusion, the author acknowledges his sincere thanks to Rao Sahib Y. Ramachandra Rao, M.A., F.R.E.S., for affording opportunities and giving all help during the earlier years of this work, and to Dr. T. V. Ramakrishna Ayyar, B.A., Ph.D., F.Z.S., for guidance in this biological control work and for encouragement, suggestions and help in the preparation of this paper.

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THE SOLITARY PHASE OF *SCHISTOCERCA GREGARIA*, FORSK., IN NORTH-EASTERN KORDOFAN (ANGLO-EGYPTIAN SUDAN).

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(PLATES IV & V.)

Introduction.

This is an account of work carried out in Kordofan on behalf of the Imperial Institute of Entomology. The period August-September 1931 was occupied with preliminary surveys and observations on hopper bands. From July to September 1932 and from March to July 1933 the ecology of the solitary phase of *Schistocerca gregaria* was studied at Um Darag; and in January 1933 a locust survey of the more northern parts was carried out.

After the preliminary work, a programme was drawn up which included a study of both phases of the desert locust. Owing, however, to the absence of swarms, the investigations were confined to the solitary phase.

Description of Country and Climate.

The area called north-eastern Kordofan for the purposes of this paper is bounded on the south by El Obeid at latitude $13^{\circ}11'N.$, on the north by latitude $17^{\circ}N.$, on the east by longitude $32^{\circ}E.$, and on the west by longitude $30^{\circ}E.$ (see fig. 3).

The climatographs showing the average monthly temperature and precipitation (fig. 1) are compiled from the Climatological Normals of the Egyptian Meteorological Office. They are selected from stations at latitudes nearly corresponding with the areas described below. Most of the data available are from river stations.

From November to February the prevailing winds throughout the Sudan are northerly. The change to southerly winds starts in March in the southern Sudan, where the rains begin early. In the central parts the south wind begins to blow in May, as the rainy season is later. Further north it may not begin till July, and in the extreme north, which is rainless, the wind may remain northerly throughout the year.

The south wind, which heralds the advent of the rains, begins to blow in northern Kordofan usually in May. It produces a sharp rise in atmospheric humidity, even though no rain has fallen. In 1933 at Um Darag there was an interval of a month between the change of the wind and the arrival of rain other than light showers (see fig. 2).

The climatograph for Atbara represents conditions farther north than the most northerly area under consideration. The latter receives an average annual rainfall of about 90 mm. The average temperature for June is about $33.5^{\circ}C.$ and for January about $20.5^{\circ}C.$ The months in which there is over 15 mm. of rain are July and August. The country is a plain of loose red sand and has very broad, gentle undulations about 20 miles wide. The vegetation consists for the most part of *Fagonia cretica*, Linn., a bush growing up to 4 ft. high, *Indigofera bracteolata*, D.C., an undershrub up to 1 ft. high, and *Aristida papposa*, Trin. & Rupr., a grass up to 2 ft. high. These plants

grow in patches, each plant being separated from its neighbour by 2-4 yards of bare sand. There are stretches of country without vegetation. This type of vegetation is called *gizzu* (Plate IV, fig. 1).

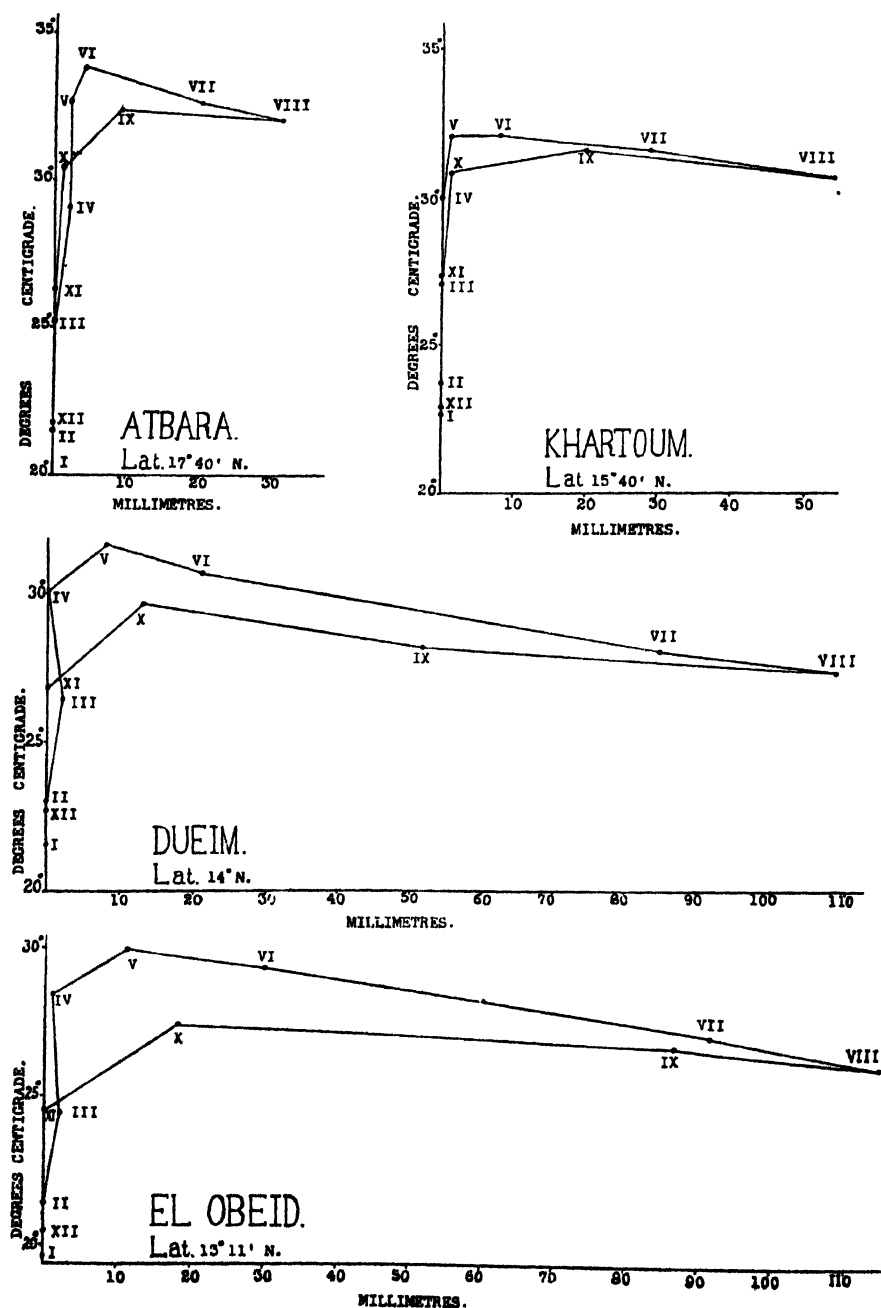


Fig. 1. Climatographs for selected stations.

Owing to the nature of the soil and the light rainfall there is no general drainage system. In the few places where there are rocky hills, wadys are formed by the rain-water and *Leptadenia spartium*, Wight., *Panicum turgidum* and other plants appear.

According to the Arabs, the *gizzu* plants do not spring up till the winter, *i.e.*, November, although most rain falls in July and August. When the area was visited at the end of January 1933, the plants were green and, in a good year, they may remain so till March.

South of latitude 16° the annual rainfall (see fig. 1, Khartoum) is in the neighbourhood of 180 mm. The months with more than 15 mm. of rain are July, August and September. The average temperature for June is about 32°C. and for January 22°C.

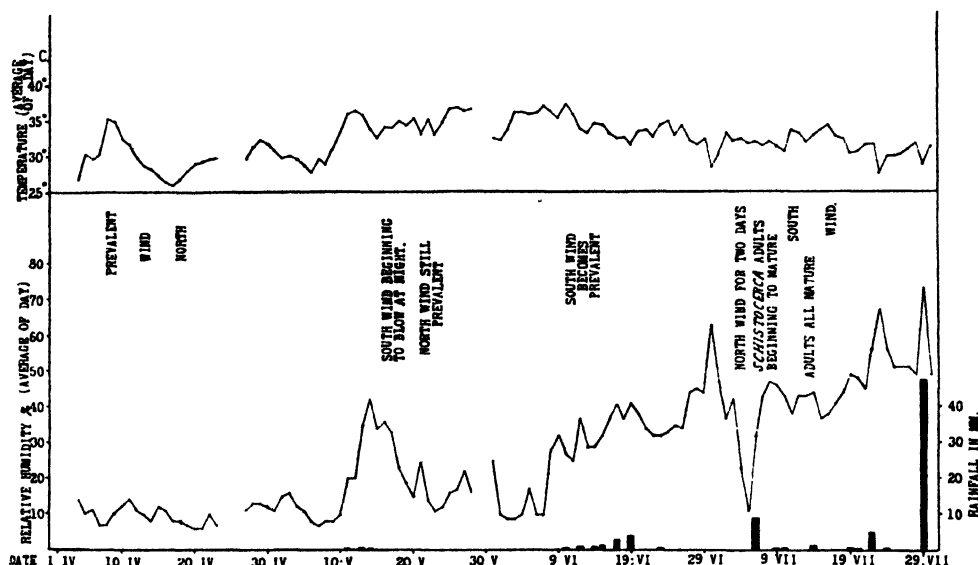


Fig. 2. Chart of weather at Um Darag, April–July 1933. The average temperature and humidity were obtained from recording instruments 10 inches from the ground among undershrubs.

In this area the ground becomes harder and patches of light clay appear, with occasional stretches of heavy, black clay. There are areas of stones and gravel and the horizon is frequently bounded by small outcrops of rock rising in places to small hills. The drainage system consists of small runnels feeding khors, which may flow into depressions and form lakes, which sometimes do not dry up until six months after the rains are over. A few large wadys flow over a long distance into the Nile. With the exception of a few lakes mentioned above, there is no water above the ground except during the rains (July–September). This type of country is called *sisá*.

The ground vegetation consists of small tufts of the annual grasses, *Aristida funiculata*, Trin. & Rupr., *A. adscensionis*, L., *A. steudeliana*, Trin. & Rupr., and *Cenchrus catharticus*, Del., which grow sometimes closely, sometimes with the tufts a foot apart. *Blepharis linariifolia*, Pers., and *B. edulis*, Pers., occur in thick patches in depressions, and in a more scattered form elsewhere.

The sides of small dry rivulets are lined with tussocks of *Cymbopogon proximus*, Stapf, *Tephrosia nubica*, Baker, *Indigofera suaveolens*, Jaub. & Spach, *Lasiurus hirsutus*, Boiss., and *Sporobolus glaucifolius*, Hochst. Larger, sandy khor-beds may contain

The *goz* country is rolling sand varying from gentle undulations to dunes 100 ft. high. These were probably caused by sand blown from the *gizzu* country and the Libyan desert beyond, by the prevailing north wind. On reaching this area of heavier rainfall, the sand was fixed by the perennial vegetation. The soil of the *gozes* is fairly hard on the surface where it has been undisturbed by agriculture. The latter has exercised a considerable influence on the soil and vegetation. This is dealt with later. The northern *gozes* are covered fairly thickly with undershrub and grasses growing 1 ft. to 3 ft. apart. There are no trees and only one bush, *Leptadenia spartium*, which grows up to 12 ft. in height (see Plate IV, fig. 2). This is usually scattered, but in some places grows as thick as trees in an orchard. South of 14°30'N. *Acacia vereh*, Guill. & Perr. (the gum-arabic tree) is common and becomes abundant towards the south, where it forms thick bush, except on the higher dunes and where the land has been cleared for cultivation (see Plate V, fig. 2). The annual grass, *Cenchrus catharticus*, which occurs over the whole *goz* country, becomes very dense in the southern parts, where it covers most of the ground between the trees and undershrubs. At about 13°30'N. the *gozes* slope down to the hard sandy plain round El Obeid, and *Adansonia digitata* (the tebeldi or baobab tree) appears. Finally the sand country ceases at the khor Abu Habil, after which heavy cotton soil begins.

There is no drainage system in the *goz* country, as all the rain-water soaks into the sand.

The vegetation on the *gozes* springs up with the rains in June or July, but remains green for longer than on the *sisa*. Certain plants remain green throughout the year. These are dealt with later (page 69). A characteristic of this sandy soil is that it dries up very slowly below the surface, so that deep-rooted perennials and trees are in contact with damp soil throughout the year. As a result, *Acacia* trees and a few perennials begin vegetative growth when the humidity of the atmosphere rises with the arrival of the south wind, even if there has been no rain.

Occurrence of solitary *Schistocerca*.

The breeding of swarms of the desert locust during the rains (July–September) of 1931 was on a much smaller scale than in the three previous years. When observations were made in the area in August and September 1931 the bands were found to be few and small. In the southern *Acacia vereh* regions where the Glossy Starling (*Lamprocolius chalybaeus*) is common, these birds congregated in large numbers round the few hopper bands. They ate large numbers of hoppers and scattered the bands, so that no swarms of adults were produced. In the northern parts where predators were not so abundant, the bands were nevertheless small, and numbers of green hoppers could be found. These, though they were sometimes with the bands, were mostly apart by themselves. They produced pale adults, and, when the small swarm joined another swarm which flew over, they remained behind. When the area was visited in November 1931, these adults were still present, and they formed a large proportion of the solitary locust population present in the summer of 1932. Their status and that of their progeny is discussed later (see measurements, p. 80).

It may be mentioned that it has not been found possible to estimate the abundance of solitary locusts satisfactorily except during the early rains, when the atmospheric humidity has risen, and when the insects are active and have not yet started dying after oviposition.

In the northern soft-sand country (*gizzu*) which was visited in January 1933, *Schistocerca* was found only in those places where *Panicum* occurred. According to the Arabs, swarms have not been known to oviposit in the *gizzu* country proper, owing to the absence of vegetation during the rains. While there is no evidence that swarms will not oviposit in damp soil in the absence of vegetation, the absence of food for the hoppers would inhibit the maintenance of a resident population of solitary locusts in the pure *gizzu* vegetation.

On the hard *sis*a, *Schistocerca* was found only where there was loose sand. In small rivulets they would sometimes be met with, and in the beds of larger khors they were numerous among the *Panicum* (see Plate V, fig. 1).

In the *goz* country they occur everywhere, except on the few parts which have never been cultivated, and among *Acacia verec* bush when it is as thick as an orchard. They are not numerous in a *Leptadenia* thicket where it is denser than an orchard. They are most abundant on the treeless *goz* with scattered *Leptadenia* (Plate IV, fig. 2). Figures for the population of *Schistocerca* and other ACRIDIDAE are given on page 77.

As the plain round El Obeid (latitude 13°30'N.) is reached, it is difficult to find a specimen of *Schistocerca*, and none are to be found on the cotton soil to the south. Latitude 13°N. is also approximately the southern boundary of breeding of swarms. As the rainfall to the south becomes heavier and the climate changes, it is difficult to say whether soil or climate is the limiting factor in distribution (see p. 75).

Work at Um Darag.

Um Darag was selected as a centre for more detailed field work, owing chiefly to the number of solitary adults present there. The place is situated at 30°9'E., 14°45'N. It is at the north-western extremity of the *gozes* and the northern limit of settlement. North of here is nomad country and the land is uncultivated.

Jebel Um Darag is a rocky hill about 1,500 feet high. To the south there is a gravel and clay wady. On the other three sides it is surrounded by *gozes* which slope down on the western side to a wady where a deep khor may flow throughout the rains.

Cultivation and its Effects.

The millets, *Pennisetum* and *Sorghum*, are grown on the sandy and clay soils respectively, together with a little cotton. The method of cultivation is as follows. During the summer the land is cleared. When sufficient rain has fallen (about 15 mm.) to penetrate about 18 inches into the soil, sowing takes place usually in July. After the herbs have sprung up to a height of about 3 inches, the land is weeded by walking between the rows of millet with a flat broad hoe, pushing up the young roots from the upper two inches of soft sand. This is done two or three times during the season. As a result of the initial clearing and of the subsequent weeding the surface of the sand gets thoroughly loosened, so that it blows about in the wind. The same land may be cultivated for several years at a stretch, when it is deserted and new ground broken. In some cases it will be sown again after three or four years. In other cases it may remain twenty years or longer without being cultivated. The result is that most of the land has been cultivated at one time or another. Farther south where the population is higher, this applies even more, and it was not possible to find any land at latitude 14°N. which was known never to have been cultivated.

About 6 miles north-east of Um Darag there were stretches of *goz* which had never been cultivated. The surface soil here is harder as it cakes after rain (see Table III). The vegetation consists of *Leptadenia spartium*, which varies in density, and the ground is covered with clumps of the sedge, *Pycneus mundtii*, Nees, and *Panicum*, with rarely a square yard of bare soil between them. Undershrubs are *Bouchea marrubifolia*, Schauers, *Melhania denhamii*, *Pavonia kotschyi*, Hochst., and *Crotalaria thebaica*. The commonest annuals are *Tragus racemosus*, All., *Eragrostis major*, Hochst., *Eragrostis tremula*, Hochst., *Cenchrus catharticus*, *Fumbristylus dichotoma*, Vahl, *Blepharis* spp. and *Ipomoea kotschyana*, Hochst. On the tops of high dunes where the sand is looser *Chrozophora oblongifolia* occurs.

When cleared land begins to be repopulated, the first plants to establish themselves are *Tephrosia obcordata*, Baker, *Chrozophora* and *Crotalaria*, and almost pure stands of the former may be produced for one year. Then *Aristida sieberiana*, Trin., makes

its appearance with *Bouchea*, *Melhanian*, *Polygala triflora*, Linn., *Tephrosia incana*, Graham, and *Pycneus*. Lastly *Panicum* becomes re-established, but in no area was the climax association found to have returned completely. The surface of the sand remains loose throughout the whole process. In an area which had been cultivated and left fallow for about twenty years, the sand surface was still much looser than on the natural *goz* (see Plate IV, fig. 2, and text fig. 4).

Certain deep-rooted perennials on this loose sand, *Chrozophora*, *Tephrosia obcordata*, *Melhania* and *Crotalaria* remain more or less green throughout the dry season. These plants are among the food-plants of *Schistocerca* adults (see Table VI).

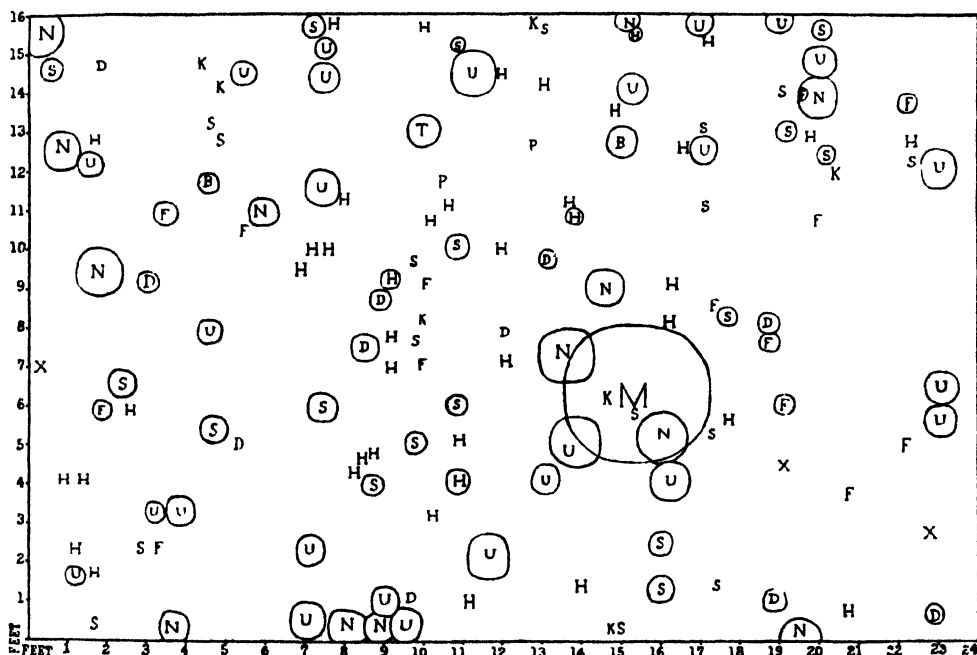


Fig. 4. Plot 16 by 24 feet at Um Darag showing vegetation on cultivated goz (area 2 on fig. 5). D=*Melhanhia denhamii*; F=*Tephrosia obcordata*; H=*Polygala triflora*; K=*Tephrosia incana*; M=*Leptadenia spartium*; N=*Crotalaria thebaica*; P=*Pavonia kotschy*; S=*Aristida sieberiana*; T=*Tephrosia nubica*; U=*Pycnus mundtii*; X=*Gisekia rubella*.

Micro-climatic Observations.

A dew-point apparatus, which enabled a sample of air from a given place to be drawn into a chamber with the mirror, was tried. It was found that at low humidities the dew-point read too low, unless a stream of air from the required place could be drawn through the chamber while the temperature was being lowered. The instrument was therefore not used for estimating the atmospheric humidity of a very small space. It was used in the jars in the maturation experiments (see p. 72).

In the field an egg-whisk wet and dry bulb hygrometer was used, where it could be inserted. In a bush this would tend to give too high a value for the humidity.

The following tables show the air temperature* and relative humidity in various situations.

* All temperatures in this paper are Centigrade.

- A. 6 inches from the surface of the ground in the open.
 B. 4 ft. " " " " "
 C. 6 inches from the ground in the middle of a shrub of *Chrozophora*.
 D. 2 ft. from the ground in the middle of a *Leptadenia* bush.

TABLE I.

Dry Season—23rd May 1933.

Time	Weather	Air temperatures °C.				Relative humidities per cent.			
		Situations				Situations			
		A	B	C	D	A	B	C	D
06-00	Sun	25.2	25.0	25.1	25.0	15	15	15	15
07-00	"	29.6	28.3	29.2	28.0	12	13	12	13
08-00	"	34.1	33.0	34.0	32.9	10	11	10	11
09-00	"	36.5	36.0	36.4	36.0	9	9	9	10
10-00	"	37.8	37.3	37.7	37.3	9	9	9	9
11-00	"	38.5	37.9	38.3	37.7	9	9	9	9
12-00	"	39.6	39.2	39.5	39.2	8	8	8	9
14-00	"	41.8	41.1	41.8	41.2	8	9	8	8
15-00	"	42.1	41.6	41.9	41.7	7	8	7	7
16-30	"	40.1	39.5	40.0	39.6	9	9	9	9
17-30	"	38.4	37.7	38.3	37.8	9	10	9	9
18-30	"	36.2	36.0	36.1	36.0	9	10	10	10

TABLE II.

Rains—3rd July 1933.

Time	Weather	Air temperatures °C.				Relative humidities per cent.			
		Situations				Situations			
		A	B	C	D	A	B	C	D
06-00	Cloudy	25.3	25.9	25.5	25.9	59	57	58	57
07-15	"	28.1	28.2	27.9	28.2	54	53	55	53
08-30	"	29.1	29.0	29.0	28.8	51	51	51	52
09-30	"	30.2	29.7	30.1	29.6	49	50	50	51
10-45	"	31.3	30.4	31.7	31.7	46	48	45	45
12-00	Sun half out	37.2	34.4	37.0	34.3	30	34	31	34
14-15	Sun	39.3	37.2	39.2	37.2	25	28	25	27
16-30	"	38.9	37.2	38.0	37.3	23	26	25	26
17-30	"	36.4	35.7	36.1	35.8	28	30	29	30
18-30	"	34.0	33.9	33.9	33.7	33	33	33	33

It is only immediately after rain when the plants are wet that high humidities are obtained. The most extreme variations in temperature are obtained on the soil surface in the open. This temperature was obtained by laying the thermometer horizontally on the ground with half the bulb below the soil. The upper half was then lightly covered with a thin layer of soil. The greatest daily range in April was 16.6° min., 62° max., on sand, and 15.3° min., 64.7° max., on clay. In May it was 24°, 73.2° on sand, and 24.6°, 75.8° on clay. The higher readings for the clay are probably due to its darker colour.

The following temperatures were taken with bright bulb thermometers suspended vertically at 12 noon :—

Soil T. in sun	...	...	...	...	...	67.7°
„ shade	...	...	...	...	...	46°
Immediately above the soil surface in sun	...	...	...	...	...	52.3°
3 inches above soil in sun	...	...	...	...	...	45.3°
3 inches above soil in shade on undershrub	...	...	...	...	...	42.1°
2 feet above soil in sun	...	...	...	...	...	42.3°
2 feet above soil in shade	...	...	...	...	...	41.8°

The readings in sun and in shade approach one another as the wind becomes stronger.

Some readings were taken in the wady. Owing to the lack of assistance no synchronised readings are available, but the method was adopted of taking readings on the *goz*, then rapidly descending to the wady and taking readings there.

In the early summer the minimum temperature is slightly lower in the wady than on the *goz* and the maximum is higher. There is very little difference in the relative humidity. During the rains there is no marked difference in relative humidity, except where there is standing water. There was no dew during March, April, May and June.

Daily Activities of *Schistocerca* Adults.

From the foregoing figures, and from Tables I and II, it will be seen that, while an insect has a wide range of temperatures from which to choose at the hottest time of the day, the range of humidities is narrow.

Observations were made to see to what extent this range was utilised by the locusts. The method employed was to find one or two adults, mark whence they flew, and place an assistant to watch them. Their position was observed at intervals with field-glasses, and the temperature taken in a similar situation near by. This value T. was obtained by placing a bright mercury thermometer with the bulb in a position similar to that of the locust with regard to height above the ground, shade and slant. During the dry season the locusts could be approached nearer than during the rains, owing to their inactivity when the humidity is low. The following account is based on three days observations in April, three days in July and various isolated observations.

During the dry season when the average relative humidity was below 20 per cent., *Schistocerca* adults were only twice observed to feed in the field, although food-plants were present in a fresh condition (see p. 68). On one occasion a piece of green millet stalk was placed near an adult in the early morning. It ate about 1 sq. cm. of leaf surface.

The night is usually spent either on a twig near the ground, or on the ground. In the former case when the air temperature reaches about 28°, the insect descends to the ground and sits broadside on to the sun. If already on the ground, it arranges itself broadside on, when the first rays strike it. When the soil temperature reaches about 45° the locust stands up, raising its body from contact with ground. T. (see definition above) in this position may be 41°. When the soil temperature reaches 50°, the locust moves into the shade or climbs a plant. Throughout the day, T. remains 38°–42°. When the sun is at its highest, the insects remain either in the shade or in such a position that the sun falls on a small area of their bodies. They rarely moved higher than 6 in. from the ground and were not observed to penetrate into a thick tussock, but remained on its outside or below it. When the soil temperature falls to about 40° they again sit on the ground. They very rarely fly if

undisturbed, and may remain for days in an area of a few square yards. However hot it may be, *Schistocerca* usually alights on the ground after a flight, and then walks to the nearest shade.

When the relative humidity is higher (30–50 per cent.), the same movements take place but with increased activity. T. still remains 38°–42°, but as maximum temperatures are much lower during the rains, the locusts spend more time on the ground. They are more easily disturbed and feed much more. Feeding may take place at any time, but usually when the soil temperature is 34°–42°, when the locusts walk about on the ground eating young shoots. When the soil becomes too hot feeding usually ceases, but may continue if the locust happens to be sitting on a food-plant, provided T. is below 40°.

Green solitary hoppers lead a very inactive, phytophilous existence compared with bands of *gregaria* hoppers. Three third instar hoppers were observed during two days in August. One descended to the ground once but immediately climbed another plant. One remained on the same plant throughout. One descended three times, staying on the ground for five minutes on one occasion. The hoppers remained in positions in which T. never rose above 38°, although temperatures up to 50° were available on the ground. Feeding took place at any temperature above 25°.

Sexual Maturation of *Schistocerca*.

Experiments to determine the causes of sexual maturation were carried out during April and May before the arrival of the rains.

Sexually immature adults from the field were separated as follows.

- A. 2 cages in the open with natural food and dry sand—10♂♂, 10♀♀.
- B. 2 cages in the open with natural food, green millet and dry sand—10♂♂, 10♀♀.
- C. 2 cages in the open with natural food, green millet and wet sand—10♂♂, 10♀♀.
- D. 2 large battery jars with natural food and wet sand—6♂♂, 6♀♀.
- E. 2 large battery jars with natural food, green millet and wet sand—6♂♂, 6♀♀.

The natural food consisted of *Chrozophora*, *Melhanian* and *Crotalaria*, which were green in the field.

The mouths of the glass jars were closed with muslin. The average temperature in the jars D and E, which were kept in the shade, was similar to that in the cages, having a lower maximum but a higher minimum. The relative humidity in the jars was estimated by means of a dew-point apparatus at 06-00, 12-00 and 18-00 hours on most days. It fluctuated between 40 and 50 per cent. The average relative humidity in the cages was below 20 per cent. throughout the experiment, with the exception of three days. The humidity was not appreciably higher in the cages with wet sand.

The results of these experiments were as follows :—

The locusts in cages A, B and C did not become mature until the rains in July, at which time sexual maturation was taking place in the field.

In the jars D and E, a certain number died and were replaced.

In D :—

- | | | | | |
|-----|---------------|--------------|---------------|------------------------------|
| 1♀ | was in copula | after 4 days | and laid eggs | 10 days later. |
| 2♀♀ | were | „ „ | 5 „ | one laid eggs 12 days later. |
| 3♀♀ | „ „ | „ „ | 6 „ | died with full ovaries. |

In E :—

1♀	was in copula	after 5 days	and laid eggs	13 days later.
1♀	"	"	6	" died with full ovaries.
2♀♀	"	"	7	" " " "
1♀	"	"	6	" died with eggs half developed.
1♀	"	"	5	" " " "

It may be concluded that the higher atmospheric humidity in the jars was the factor which induced sexual maturation. It is of interest, however, that the locusts in the jars ate at least four times as much food as those in the cages. It is possible, therefore, that the increased humidity affected the maturation process only indirectly, by stimulating the insects to feed.

This conclusion is borne out by observations in the field. A recording thermohygrograph was set up 10 inches from the ground supported by a wooden framework shaded by a narrow thatch from the direct rays of the sun. It was placed in the field among undisturbed shrubs. A thin thorn fence was set up round the structure to keep out domestic animals. The hair hygrograph was inaccurate, but the graph was corrected from whirling hygrometer readings five times a day. The average daily temperature and relative humidity were calculated from these graphs and are shown graphically, together with the rainfall, in fig. 2.

The first rise in relative humidity comes with the south wind. This blows intermittently at night when it first comes, but later displaces the north wind during the day. At Um Darag in 1933, no rain, other than light showers which dried up without penetrating the soil, fell until 6th July. But the average relative humidity rose to above 30 per cent. after 9th June, as may be seen from fig. 2. A female *Schistocerca* with yolk deposited in the ovaries was first found on 7th July.

At Abu Hadid, 15 miles away, where heavy rain had fallen on 19th June and subsequently, and where the vegetation was green much earlier, the first mature female was found on 3rd July. This indicates that the more luxuriant vegetation had had little effect on the rate of maturation; but it must be remembered that food-plants were present at Um Darag in spite of the absence of rain. On the other hand, at Abu Hadid, where moist soil was available earlier, 4th instar hoppers of *Schistocerca* were found on 7th August, at which date they were still of the 1st and 2nd instar at Um Darag. This indicates that oviposition was delayed at Um Darag owing to the soil being dry. This conclusion is supported by an observation at Um Darag on 22nd July. Two females were observed to insert their abdomens into the dry sand several times without ovipositing, although dissection showed their ovaries to be full. Females in cages with wet soil first oviposited on 17th July.

The conclusions to be drawn from the foregoing observations and experiments are that, while atmospheric humidity causes sexual maturation, rainfall is necessary for oviposition.

The eggs which were laid in jars D and E had incubation periods of 9, 10 and 10 days, as opposed to 20–22 days in August 1932. The average temperature of the soil in the jars is not known accurately, but it was certainly very much higher than in August 1932. The resultant hoppers in June 1933 acquired wings 30–34 days after hatching as opposed to 42–50 days in August 1932. The average temperature of the air in the cage in which the hoppers were reared in June 1933 was 32°–35°, as opposed to 27°–32° in August 1932.

These hoppers reared during the dry season in 1933 acquired wings at the end of June and only five pairs survived. They were kept in a cage outside with adults from the field. The latter were mature by 10th July, but the young summer-bred adults were only beginning to mature on 8th August, although they had been subject to the same conditions which induced maturation in those from the field.

This suggests the possibility of a second generation after only a short diapause. In the season July 1932-1933 there was only one generation of solitary *Schistocerca* at Um Darag. The adults were sexually mature in July 1932, oviposited and mostly died. Their progeny were adult by the end of September 1932, and became sexually mature in July 1933, after a diapause of nine months.

Dissections were made once a month, in order to observe the condition of the fat-body. At the end of May, the fat-body appeared to the eye just as well developed as at the end of March. When maturation took place, this organ decreased in size, as the eggs in the ovaries grew. The fat-body was larger in the females than in the males.

Sexual Maturation of other Acrididae.

The life-cycle of most of the ACRIDIDAE is not known fully, but the following observations are of interest.

In January 1933, *Acridella* sp., *Platypterna* spp., *Pyrgomorpha cognata*, and *Catantops saucius* were found sexually immature in northern Kordofan. During the summer (April-May) 1933 a few 4th and 5th instar hoppers of *Platypterna* and *Pyrgomorpha* were found in Um Darag. This indicates that at least one generation was produced after the rains, and that the lack of suitable food-plants (see Table VI) for the hoppers of *Pyrgomorpha* and *Platypterna* slowed down their development during the summer months. Of the other Acridids in the association, all became sexually mature in the early rains at the end of June at Um Darag, but a little earlier than in the case of *Schistocerca* (see also page 72).

Soils and Oviposition.

Experiments in oviposition were carried out in cages 2 ft. 6 in. by 1 ft. 6 in. by 2 ft., in which about 40 pairs of adults from the field were enclosed. The floor of each cage was a drawer containing five zinc trays 5 inches in depth. This drawer could be withdrawn for examination. The four soils used for the experiments were :—

1. Soil from goz left fallow for five years (Area 2 in fig. 5, p. 75).
2. Soil from lower goz, left fallow for two years.
3. Soil from uncultivated goz (Area 4 in fig. 5 p. 75).
4. Soil from sisa in the wady.

Analyses of these soils were as follows :—

TABLE III.

No.	Stones and gravel	Coarse sand	Fine sand	Silt	Clay	Salts	Capillary rise
1	% 0.0	% 71.2	% 23.0	% 2.0	% 3.9	% .064	mm. 145
2	0.0	80.7	15.8	0.2	3.2	.007	120
3	0.0	75.2	19.0	2.6	3.2	.014	156
4	0.0	23.9	30.8	8.3	36.8	.031	215

The Government Chemist, Khartoum, adds "I am of the opinion that the hardening of the uncultivated soil No. 3 is due to the higher percentage of iron oxide (as indicated by colour), which acts as a cementing material." The iron oxide presumably gets leached out from the surface of the cultivated land.

The results of the oviposition experiments were as follows :—

TABLE IV.

Cage 1 Soil watered daily		Cage 2 Soil watered every third day	
Soil No.	No. of egg-pods	Soil No.	No. of egg-pods
1	5	1	9
2	11	2	14
3	0	3	0
4	0	4	0

It may be noticed that the preferred soil (No. 2) had the highest percentage of coarse sand, and the lowest percentage of fine sand, silt and clay.

These results, while not conclusive, indicate that soil is the limiting factor in the distribution of solitary *Schistocerca* in an area of fairly uniform climate.

Ecological Observations on Acrididae.

The principal method used for estimating the population of grasshoppers was as follows :—

Areas were pegged out in several localities and the observer walked up and down counting all the individuals of each species seen. Three sizes of area were used, according to the distance which a given species would fly when disturbed. For the larger species, *Schistocerca*, *Ornithacris*, *Acridella*, the areas were 300 by 150 yds., and 10 walks were made at 30-yard intervals. The eyes were directed nearly horizontally as the insects concerned are conspicuous. For the medium-sized species, such as *Catantops*, the areas were 90 yards square and ten walks were made at 9-yard intervals. For the smaller species, such as *Tenuitarsus*, the areas were 50 yards square and 10 walks were made at 5-yard intervals. In the latter case the observer walked slowly with the eyes directed downwards.

At first observations were made at various times during the day. When it had been ascertained at what temperatures the maximum number of each species was seen, the counts were thereafter made when these conditions obtained. Counts were made by this method every month and the maximum number obtained was assumed to represent the population of that area. The figures were then reduced, for each species, to the number in 100 yards square. This method was found unsatisfactory for some phytophilous species of which the population was estimated by catching as many as possible in a given area. On the hard *sisa*, also it was not found possible to utilise the counting method, as the conditions are not so uniform as on the *goz*, and vary considerably over a small area.

The following is a list of species collected with notes as to their distribution. The term cultivated *goz* refers to *goz* that has been cultivated, not to that actually in cultivation.

I. Species occurring on *goz* and on *sisa*.

A. Geophilous species.

Chrotogonus sp.—Occurs in open spaces, at the edges of clearings.

Acrotylus blondeli, Sauss.—Occurs on all *goz* country and on more sandy tracts of *sisa*.

B. Intermediate species.

Pyrgomorpha cognata, Kr.—Abundant on *goz* and *sisa*.

Caloptenopsis insignis clarus, Wlk.—Common on cultivated *goz*, and among *Cymbopogon* on *sisa*; less abundant on uncultivated *goz*.

Stenohippus aequus, Uv.—On *goz* and sandier tracts of *sisa*.

Oedaleus senegalensis, Kr.—Abundant everywhere, but difficult to find in the dry season.

Trilophidia sp.—One specimen taken on small millet bed on *goz* in April. Two specimens taken among young *Juncellus* near water in the wady in August.

C. Phytophilous species.

Catantops haemorrhoidalis, Kr.—Occurs in most undershrubs, but is very inconspicuous.

Thisiocetrus littoralis, Ramb.—Usually associated with the bush *Leptadenia spartium*, and hence commonest on *goz*.

Acridella sp.

Platypterna nubica, Wern.—Not common.

Anacridium moestum, Serv.—Associated with trees. Common on southern *gozes*.

II. Species occurring on *sisa* only.

A. Geophilous species.

Sphingonotus canariensis, Sauss.—Occurs on hard, stony ground. Commonest on rocky slopes near hills.

S. rubescens, Wlk.—Occurs on hard ground, but not actually on stones.

S. savignyi, Sauss.—Taken on hard ground, and once on *goz*.

Gen. nov. near *Sphingonotus*.—As *S. savignyi*.

Thalpomena aurora, Karny.—As *S. rubescens*, but occurs on stones.

B. Intermediate species.

Aiolopus affinis, I. Bol.—Taken among trees.

Aiolopus sp.—On heavy clay.

Tylotropidius sp.—One specimen on hard sandy ground.

Stenohippus xanthus, Karny, and *S. mundus*, Wlk.—On heavy clay.

Acrotylus patruelis, H. S.—Taken among thick *Juncellus* near water.

Euprepocnemis sp.—One specimen taken among *Cymbopogon* on clay.

C. Phytophilous species.

Platypterna sp.—One specimen.

Pnorisa sp. n.—Common among *Cymbopogon* on heavy clay.

Aulacobothrus sp. n. and *Platypternodes* sp. n.—Among *Sporobolus* on heavy clay.

III. Species occurring on *goz* and sandy khors on *sisa*.

A. Geophilous species.

Tenuitarsus sp.

Acorypha houi, Ramme.

Acrotylus longipes, Charp.

B. Intermediate species.

Catantops saucius, Burm.*Ornithacris cyanea tereticollis*, I. Bol.*Stenohippus gracilis*, Wern.*Schistocerca gregaria*, ph. *solitaria*.

C. Phytophilous species.

Acridella procera, Kl.*Ishnacrida pallida*, Burm.*Mesopsis* sp.*Platypterna nilotica*, Salfi.*Platypterna* sp. n.**Acridid Population on Goz.**

The following table (Table V) shows the relative density of the number of different species on four goz plots.

TABLE V.

Species	Method of estimate	Area 1		Area 2		Area 3		Area 4	
		%	Number per 100 yds. sq.	%	Number per 100 yds. sq.	%	Number per 100 yds. sq.	%	Number per 100 yds. sq.
<i>Schistocerca gregaria</i>	A	0.8	4	0.9	6	0.4	1	Nil	Nil
<i>Ornithacris cyanea tereticollis</i> ...	A	2.2	12	1.8	8	0.8	2	Nil	Nil
<i>Stenohippus gracilis</i>	C & D	5.7	30	3.6	25	11	25	3.4	8
<i>Stenohippus aequus</i>									
<i>Catantops saucius</i>	B	43	222	44	312	9.4	21	1.7	4
<i>Catantops haemorrhoidalis</i> ...	D	1.2	6	0.3	2	0.8	2	Nil	Nil
<i>Pyrgomorpha cognata</i>	C	8	40	5.7	40	5.4	12	24	55
<i>Acorypha houi</i> ...	C	11.4	60	6.8	48	18	40	5.2	12
<i>Caloptenopsis insignis clarus</i> ...	B	0.8	4	2.3	16	7.2	16	1.7	4
<i>Chrologonus</i> sp. ...	C	0.4	2	0.3	2	Nil	Nil	Nil	Nil
<i>Thisiocetrus littoralis</i> ...	A	1.4	8	1.7	12	0.8	2	3.4	8
<i>Acridella procera</i> ...	A	0.4	2	0.1	1	0.8	2	0.9	2
<i>Tenuitarsus</i> sp. ...	C	4.6	24	3.6	25	1.7	4	3.4	8
<i>Ishnacrida pallida</i>	A	1.5	8	0.1	1	2.2	5	3.0	7
<i>Mesopsis</i> sp. ...	D	0.2	1	Nil	Nil	0.4	1	0.4	1
<i>Platypterna nilotica</i>	D	6.1	32	2.1	15	11	24	3.4	8
<i>Platypterna nubica</i>									
<i>Platypterna</i> sp. n.	C	4.6	24	17	120	5.4	12	30	70
<i>Oedaleus senegalensis</i>									
<i>Acrotylus longipes</i>	C	1.5	8	4.5	32	5.4	12	3.4	8
<i>Acrotylus blondeli</i>	C	6.2	32	5.7	40	20	44	16	38

A indicates that the estimate was made by counts in the 300×150 yd. areas.

B " " " " " " " " 90×90 "

C " " " " " " " " 50×50 "

D " " " " " " " " the collecting method.

Area 1 is goz left fallow for about 5 years.

" 2 " " " " 20 "

" 3 is low goz where it slopes down to the wady left fallow for 5 years.

" 4 is uncultivated goz.

see
fig. 5.

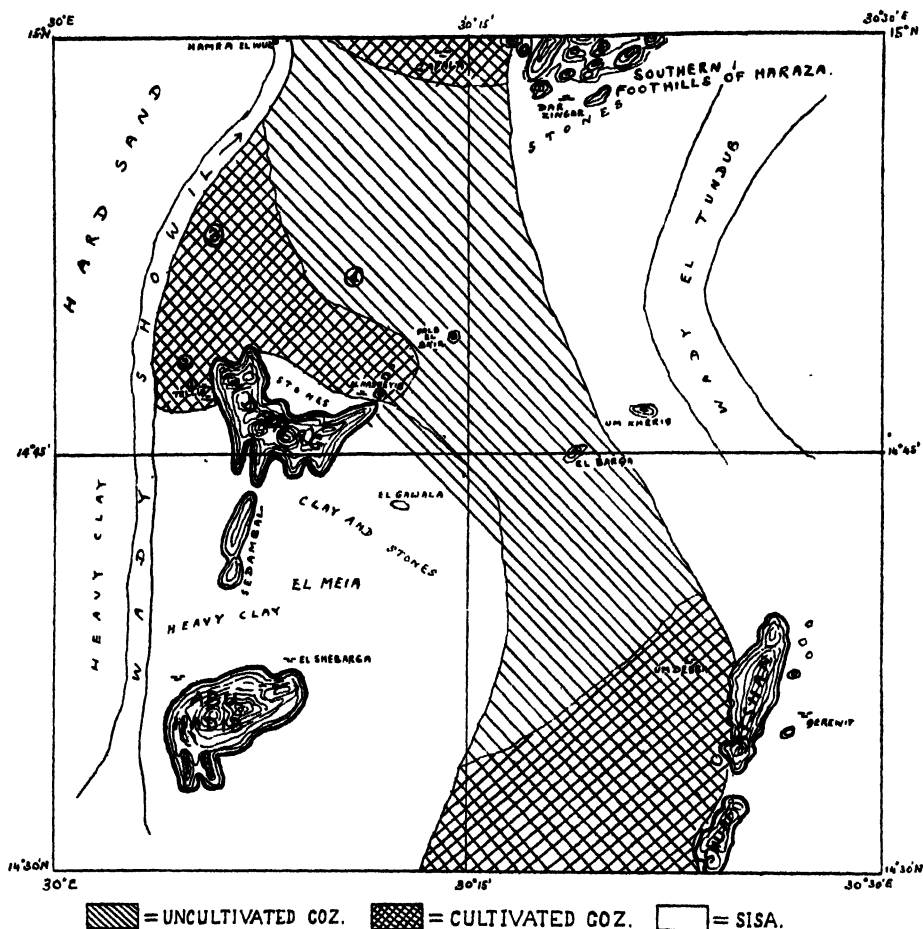


Fig. 5. Environs of Um Darag.

It will be seen from the table above that the solitary *Schistocerca gregaria* forms but a small part of the Acridid population in any habitat. In 1932 no estimates were made of the general Acridid population, but the density of *Schistocerca* was much greater. These were the parents of those counted in 1933, and their numbers were about 30 per 100 yards square in Area 2.

Of the above species, *Schistocerca*, *Pyrgomorpha*, *Oedaleus*, and *Acrotylus blondeli* are inactive during the dry season. It was difficult to find a single specimen of *Oedaleus* in May although this species was so much in evidence later.

The activity of the remaining goz ACRIDIDAE is considerable during the dry season. *Catantops saucius* appears less active when sexually immature, at which period it darkens in colour.

The grasshoppers of the *sis*a are mostly inactive during the dry season, possibly because the plants are all withered.

The colour of the solitary adults of *Schistocerca* is light cream and pale grey. When bred in areas where there is much of the grass *Cenchrus*, they are more straw-coloured, as this annual is usually withered before the hoppers are adult. On the Red Sea coast where much of the *Panicum* grass is withered and grey, this colour predominates in *Schistocerca* adults. Pale adults when caged at Um Darag, darkened in colour. No general colour change was observed when maturation took place.

The solitary phase of *Locusta migratoria migratorioides* is not apparently resident in northern Kordofan. The only evidence pointing to a possibility of its presence was the discovery of a few *solitaria* or *transiens* adults with stragglers from swarms among the vegetation at Um Darag in July. But as no *Locusta* had been seen during the dry season, it is probable that these adults had immigrated with the swarm.

Food Preferences of Acrididae.

Some experiments were carried out on this subject with some of the common grasshoppers.

TABLE VI.

Acridid	Date	<i>Panicum turgidum</i>	<i>Euphorbia</i> sp.	<i>Polygala triflora</i>	<i>Tephrosia obcordata</i>	<i>Melhania denhamii</i>	<i>Chrozophora oblongifolia</i>	<i>Crotalaria thebaica</i>	<i>Leptadenia spartium</i>	<i>Aristida sieberiana</i>	<i>Tephrosia incana</i>	<i>Sorghum vulgare</i>	<i>Pavonia kotschy</i>	<i>Indigofera suaveolens</i>	<i>Bauchea marrubifolia</i>	<i>Ipomoea kotschyana</i>
<i>Schistocerca</i>	5.vi	4	4	5	2	1	2	3								
<i>Schistocerca</i>	10.vii		3	4	3	4	2	3			5	1	5			
<i>Schistocerca</i>	6.viii		2	5	1	1	1	3				1	2	2	3	4
<i>Caloptenopsis</i> & <i>Acorypha</i> ...	2.vi	3	2	1	3	4	5	5								
<i>Thissocetrus</i>	18.vi	4	4	5	1	1	5	5	1							
<i>Catantops saucius</i>	18.vi	5	2	3	3	2	2	4	5							
<i>Tenuitarsus</i>	8.vi	5	1	5	5	4	4	4								
<i>Chrotogonus</i>	8.vi	5	1	5	5	4	3	4								
<i>Acridella</i>	1.vii	1	5	5	5	5	5	5								
<i>Stenohippus</i> spp.	23.vi	1	5	5	5	4	5	5								
<i>Platypterna</i> spp.	22.vi	1	5	5	4	5	5	5								
<i>Ornithacris</i>	20.vi	1	5	5	2	3	1	5	5							
<i>Ishnacrida</i>	4.vii	1	5	5	5	5	5	4								
<i>Oedaleus</i>	18.vii	1	5	5	5	4	4	5			5					
<i>Pyrgomorpha</i>	26.vii	5	5	1	3	2	2	5		5	5					

The method employed was to cage about twenty individuals and provide them with approximately equal quantities of each plant to be used. In the dry season the green perennials were tested.

In the above Table (Table VI) the figure 1 in the column of the given plant means that that plant is largely eaten, 2 that it was about half finished, 3 that it was a quarter finished, 4 that it was nibbled, 5 that it was untouched. Where a column is blank, it means that the plant was not used in the experiment.

It will be seen that *Schistocerca* is a very catholic feeder, and that its food-plants include those which are green all the year round on the *gozes* (see p. 69).

Movements of Acrididae.

There is no evidence that migration takes place other than very local movements to food. Grasshoppers of the *sis*a do not migrate to the *goz* for green food in the dry season, but remain inactive in the wady. But they will concentrate on grassy areas in the wady during the rains. The *goz* in this respect is more uniform, as there is never any standing water.

On 10th May, the south wind blew for the first time in 1933. There was a sand-storm and light rain. The latter did not penetrate the ground except in one area of about one square mile where the rain was heavier. The wind then returned to the north. This area was visited a fortnight later when the vegetation was springing up. It had previously been roughly surveyed for solitary *Schistocerca*, which were not numerous, as the place is in the *sis*a belt. The population was in the neighbourhood of 1 to a 400 yard square. When the vegetation had sprung up after the rain the population had risen to about 3 to a 400 yard square, while outside the area of rain none were to be found within 2 miles of its edge. Being on the harder sand where the vegetation all dries up in the dry season, this movement was probably a concentration to food. The locusts, however, were still sexually immature, doubtless owing to the fact that the rain had made very little difference in the atmospheric humidity, as the wind had returned to the north.

Chrotogonus, *Tenuitarsus*, *Pyrgomorpha* and *Acridella* were here found sexually mature, while at Um Darag they were still immature.

The early rains which fell at Abu Hadid (see page 73) provided an opportunity of seeing whether any large concentration would take place to this area, from the surrounding country, which was still dry. Had any such concentration taken place its effect on the population at Um Darag would have been noticed. There was, however, no concentration of this sort.

An apparent concentration to a small area on which rain had fallen was observed on the Red Sea coast in December 1932. The vegetation had sprung up, and the concentration was probably due to this. Atmospheric humidity was probably not a cause, as the atmosphere on the coast is always humid. As the Red Sea littoral is very barren, a concentration to food-plants might well occur. As has been pointed out, food is never likely to be a limiting factor in the Kordofan *goz* country.

Measurements of *Schistocerca*.

Measurements were made of numbers of *Schistocerca* of various phases from different localities. Graduated callipers were used and all the specimens were dead, dry and unmounted.

The following features were used :—

Length of the elytron = E.

Length of the hind femur = F.

Length of the pronotum in the median line of the dorsal side = L.

Breadth of the pronotum in its most constricted place = B.

The average of various ratios of these values is given in Table VII.

The following are the locusts measured :—

- A. 130 males and 68 females from a sexually mature swarm taken at Wad Medani (H. B. Johnston, 19.vii.30).
- B. 24 males and 22 females from a small, young swarm. Northern Kordofan, 19.ix.31.
- C. 45 males and 92 females from a very small mature swarm. Red Sea Coast, 15.xii.31.
- D₁. 31 males and 40 females from Khor Arbaat on the Red Sea Coast, 10.xii.31. These were young adults and not very numerous. Their origin is obscure. They are of the phase *transiens*.
- D₂. 100 males and 100 females. Khor Arbaat, 13–20.i.32. These were in the same locality as D₁ but younger. They were not the offspring of D₁. They were much more numerous, and mostly pink in colour. They are of the phase *transiens* but nearer *gregaria* than D₁.
- E. 75 males and 100 females. Um Darag, 17–20.vii.32. These are of the phase *transiens* and probably *dissocians*. They were bred in the field in August–September 1931, and spent the following dry season *in situ*, becoming mature in July 1932. These became adult at the same time as B.
- F. 100 males and 100 females. Um Darag, 23–28.ix.32. These are young adults, the progeny of E. They spent the dry season *in situ* and became mature in July 1933. They were less numerous than their parents. There was no breeding of swarms in this region in 1932. These specimens approach *solitaria*.

TABLE VII.

Serial Number	E/F		B/L		E/L		E/B		F/L		F/B		No. of specimens	
	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
A	2.27	2.32	.595	.620	5.55	5.70	9.33	9.22	2.44	2.46	3.96	3.97	130	68
B	2.23	2.27	.609	.625	5.68	5.77	9.35	9.25	2.55	2.52	4.18	4.08	24	22
C	2.24	2.31	.589	.613	5.23	5.76	8.91	9.40	2.54	2.49	4.31	4.07	45	92
D ₁	2.08	2.11	.584	.601	5.47	5.68	9.36	9.47	2.62	2.69	4.49	4.48	31	40
D ₂	2.16	2.20	.570	.596	5.43	5.60	9.52	9.38	2.52	2.54	4.42	4.26	100	100
E	2.14	2.30	.585	.606	5.53	5.68	9.44	9.38	2.45	2.47	4.19	4.09	75	100
F	2.05	2.11	.577	.595	5.43	5.57	9.42	9.35	2.65	2.64	4.59	4.43	100	100

In considering the above table, it must be borne in mind that A are from a large swarm, B and C from small swarms, D₁ and D₂ are *transiens*, with D₂ nearer *gregaria* than D₁; while E are solitary in habit but containing a large number of *dissocians* individuals; F are the progeny of E, similar to them in habit but less numerous. We may therefore expect a marked difference in the biometric ratios of A and F.

The ratio E/F exemplifies this difference giving us as the order of descent from *gregaria* to *solitaria*, A, C, B, D₂ and E, D₁, F. If the ratio F/B is considered the order would be A, B and E, C, D₂, D₁, F. The other ratios do not appear to be of any value.

The apparent proximity between B and E, which were of the same generation in 1931, is interesting. Although E appear of the solitary colour and habit, they structurally resemble the *gregaria* of the same generation more than they resemble their offspring. It is a moot point whether the latter should be considered as true *solitaria*, there being unfortunately no long series of solitary *Schistocerca* from other places for comparison; the following measurements are, however, given, though the specimens are too few to be of much value for comparison. These are all so-called solitary locusts, in the possession of the Imperial Institute of Entomology.

1930 Turkana Desert. 2♂♂2♀♀, E/F♂ = 2.12, E/F♀ = 2.29.

Bred in Jerusalem Insectary. 1♂1♀, E/F♂ = 2.02, E/F♀ = 2.17.

1932 Southern Libyan Desert. 6♀♀, E/F = 2.09.

1875 Cape Verde Islands. 3♀♀, E/F = 2.10.

The females from the Libyan Desert are apparently more extreme *solitaria* than F. In the author's opinion F may be regarded as phase *solitaria* for all practical purposes.

Conclusions.

The work in Kordofan has revealed the fact that solitary desert locusts have been established there for at least two years in considerable numbers. The first generation studied were partly composed of stragglers from hopper bands and flying swarms. The second generation, produced in the absence of swarms, is shown by measurements to differ from its parents in the direction of *solitaria*, if indeed it has not actually this status. It has been established that these locusts exist throughout the dry season, from September to June, in a state of sexual immaturity. They become sexually mature in July, and after oviposition, most of them die.

Experiments indicate that, while a mere increased atmospheric humidity will induce sexual maturation, moist soil and therefore rainfall is necessary for oviposition.

Experiments on oviposition indicate that sandy soil, of which the surface is loose, is an important factor in the distribution of solitary *Schistocerca*.

Of the three edaphic and climatic divisions into which the area is divided, the sandy *gozes* in the southern half of the area show by far the highest population of locusts. It has, however, been shown that agriculture has so modified the surface of the *gozes* as to render them suitable for *Schistocerca*; for on *gozes* which had never been cultivated no locusts were found, except on the tops of occasional high dunes where the sand was loose. In other words the *gozes* appear to be an artificially produced habitat for solitary locusts.

Observations have shown that, while concentration may occur to food, it probably does not do so merely to rainfall. On the *gozes* there is a perpetual supply of food-plants throughout the year, and it seems unlikely that any concentrating factor could occur there, as there is probably sufficient rain every year for the breeding of the solitary locusts throughout the area.

On the *sis*a there is no green vegetation during the dry season, so that concentration could occur to the herbage springing up as a result of early local rain. This is shown to have happened on one occasion in 1933. But the *Schistocerca* population of the *sis*a is small, as the locusts are found only where there is loose sand.

In the northernmost area (the *gizzu*) the sand is loose and therefore suitable for solitary locusts, but they were not found on the typical *gizzu* country, but only where there was ground water with *Panicum* and *Chrozophora*. According to the

Arabs, the *gizzu* vegetation does not become green until the winter, *i.e.* after the rains. This absence of food during the breeding season might account for the scarcity of locusts. As the rainfall is less and more variable than in the south, a concentration might well occur to food in years when there were areas which received no rain. If there followed a few favourable seasons, an increase of numbers among the concentrated locusts might produce a phase *congregans*. This is, however, mere speculation, as the *gizzu* area has been visited once only, so that very little is known about it. Further work might reveal whether such concentrations are actually capable of occurring.

Acknowledgments.

The author wishes to record his thanks to Mr. B. P. Uvarov for identification of ACRIDIDAE and for much assistance especially in preparing this paper; Mr. H. B. Johnston for valued guidance and help; Mr. H. W. Bedford for advice and assistance in Khartoum; Mr. B. W. Whitfield for analysing soil samples; and Mr. R. E. Massey for identification of plants.

EXPLANATIONS OF PLATES IV AND V.

Plate IV.—Fig. 1. "Gizzu" country near Abu Tawaqia. *Indigofera bracteolata* in foreground ; *Fagonia cretica* in the middle distance, with *Aristida papposa* amongst it, but not showing up.

Fig. 2. Cultivated "goz" (area 2 on Fig. 5). A bush of *Leptadenia spartium* ; and tussocks of *Pycneus mundtii*, *Aristida sieberiana*, *Tephrosia obcordata* and *Melhania denhamii*.

Plate V.—Fig. 1.—A sandy khor in the "sisá" country. The shrubs are *Chrozophora oblongifolia*, and the grass *Panicum turgidum*.

Fig. 2. Cultivated "goz" in the south, near Bara. A *Leptadenia* bush on the left ; trees of *Acacia vereh* ; ground vegetation represented by *Aristida sieberiana* and *Cenchrus catharticus*.



Fig. 1.



Fig. 2.



Fig. 1.



Fig. 2.

THE INFLUENCE OF TEMPERATURE ON THE ACTIVITY OF SHEEP-BLOWFLIES.

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A knowledge of the influence of temperature on the activity of blowflies should help us to interpret the results obtained by trapping in the field under known weather-conditions, and to foretell under what conditions, and in what districts, blowflies are likely to be active. For these reasons the following experiments were undertaken, using four species of blowflies known to be of particular importance to the sheep-blowfly problem. These are: *Lucilia cuprina*, Wied., *Lucilia sericata*, Mg., *Chrysomya rufifacies*, Macq., and *Calliphora stygia*, Fabr.

1. The Quantitative Methods Used.

The method used by Bodenheimer (1929) and Chapman and others (1926) of classifying descriptively the kinds of activity that occur at different temperatures was found by preliminary experiments to be unsatisfactory for the study of the activity of blowflies. Moreover, it was not found possible to measure the speed of movement, which seemed to be the most natural way of recording activity. Ultimately it was decided to record for each temperature the number of flies exhibiting each of the following easily-recognisable types of behaviour:—

1. *Coma*: legs commonly strongly flexed; flies usually lying on backs.
2. *Rest*: no movement; legs and body in normal resting attitude. In practice this is easily distinguished from coma.
3. "*Movement*": this term is here confined to movements other than those of locomotion; it includes cleaning, feeding, and the small movements of legs and body that often precede and follow crawling and flight.
4. *Crawling*: self-explanatory.
5. *Flight*: self-explanatory.

Attempts were made to subdivide some of these categories, but without success. It should be particularly noticed that any or all of these types of behaviour may occur simultaneously in a population of flies at any given temperature; they are not stages in the progressive change of activity with temperature, as are the phases recognised by Bodenheimer (1929) and Chapman and others (1926).

The procedure was to record the number of flies observed at a glance exhibiting each type of behaviour, and to make large numbers of such observations of each species at each temperature. Experience showed that six flies in each observation-jar was a convenient number to use, as with larger numbers there was commonly a marked change in activity during the time necessary for observation. When making these observations, however, flight was ignored, owing to the difficulties caused by its very short duration in the small observation-jars. For the record of flight separate observations for periods of one minute each were made and the number of individual flights counted. A record was also kept of the number of flies observed to be situated on the corks of the observation-jars, for it was thought that this might indicate the temperatures found to be uncomfortable by the flies of each species.

2. Experiment with a Series of Constant Temperatures.

1. Apparatus.

Two slightly different types of observation-jars were used, one consisting of a 200 cc. beaker, and the other of a tubular bottle 2 ins. in diameter and $4\frac{1}{2}$ ins. high. The details of the equipment of these and the method of their suspension in the waterbath are shown in fig. 1. Provision for exchange of air is provided by a hole in the cork containing a crumpled mass of butter-muslin and, in one type (fig. 1, B), by an open tube sufficiently narrow to prevent egress of the flies. It was found that the flies readily sucked water from the butter-muslin plug of the inverted bacteriological fermentation tube (fig. 1, s). The food consisted of a raisin split in halves, which experience has shown to be a satisfactory food for the maintenance of the activity of blowflies. A piece of white blotting-paper, extending from top to bottom and half way round the inside of the observation-jar, provided a suitable surface for the flies to rest upon. Temperature was recorded by a thermometer having its bulb in the centre of the observation-jar.

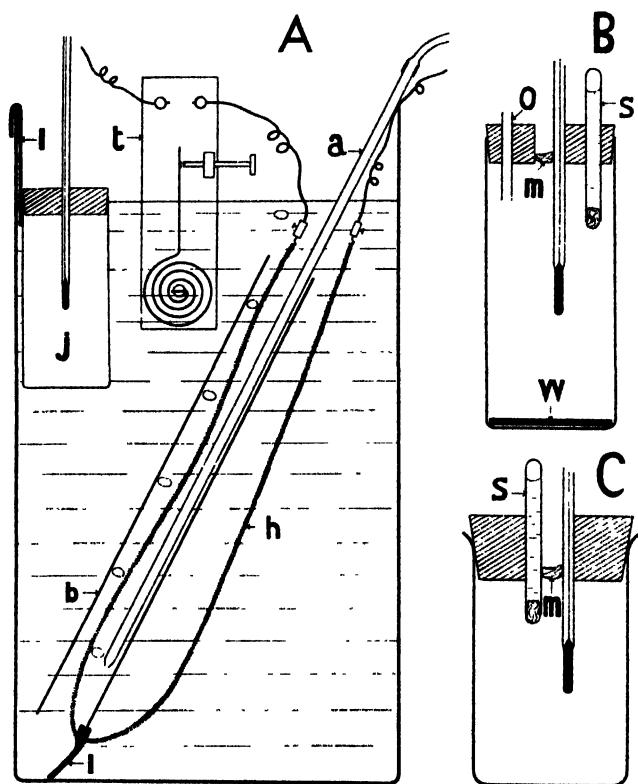


Fig. 1. A, constant-temperature waterbath; B and C, observation-jars. *a*, air-supply tube; *b*, wide tube directing bubbles and water current; *h*, heating element; *j*, observation-jar; *l*, lead support; *m*, crumpled butter-muslin; *o*, open tube; *s*, water-supply vessel; *t*, thermostat; *w*, lead weight.

The constant-temperature waterbaths (fig. 1, A) consisted of large glass battery-jars. The temperature was maintained by means of a simple thermostat, of the type using a bimetallic strip, the heating element being a length of nichrome wire, such as is commonly used in electric radiators. The water was continually stirred by bubbles passing up a wide glass tube, the open ends of which were respectively about an inch from the bottom of the waterbath and an inch below the surface

of the water. With this apparatus it was found possible to maintain the temperature inside the observation-jars within a small fraction of a degree of the temperature required.

At 5°, 10°, and 15°C. a carbon-filament bulb was substituted for the nichrome wire, because the current passing between the thermostat and the nichrome wire, even when the points of the thermostat were separated, was sufficient by itself to raise the temperatures above that required.

At 10°C. it was necessary to cool the water during the day. This was accomplished by means of ice in a weighted bag of silk which was moved up and down by a string when the temperature was observed to be too high. This primitive method was found to be very satisfactory and little trouble.

At 5°C. the same method was used but, in addition, a large block of ice was sunk in the waterbath, and the top was kept covered by a sheet of cardboard on which a metal tray of ice was placed.

At 2°C. and 0°C. the flies were placed in test-tubes containing blotting-paper on which the flies could rest. These tubes were plugged with rubber bungs, weighted with lead, and sunk, inverted, in a large beaker of ice and water, which in turn was placed in an electric refrigerator.

2. Preliminary Experiments.

Preliminary experiments, in which *L. cuprina* was used, were made to determine whether the methods and apparatus were satisfactory. These showed :—

1. That the observation-jars used were satisfactory for the flies. (Five jars, containing six flies each, were maintained at 25°C. for six days. At the end of this time the flies appeared to be just as healthy as when they were put into the jars, and counts revealed only a slight reduction in activity. There was no mortality.)
2. That twenty-five observations of a set of six flies gives a satisfactory record of the activity of the flies. (Two groups of twenty-five observations of each of five sets of six flies were taken in quick succession. The results so obtained were closely similar.)
3. That six flies taken at random do not give a satisfactory average sample of a population. (Five groups of twenty-five observations were made of each of five sets of six flies. Variations in the successive groups of observations of the same set of flies were generally small, but the variations in the activity between different sets of flies were marked and consistent.)

3. Conduct of Experiment.

In view of the above results, it was decided to use five sets of six flies of each species at each temperature and to make twenty-five observations of each set of flies, so obtaining 750 observations of individuals of each species at each temperature. These figures apply to three of the species used ; for the remaining species (*C. stygia*) there were only 500 observations of individuals at each temperature. Flies of this species are much larger than the others examined, and it was therefore decided to use only four, instead of six, individuals in each observation-jar. In other respects all the species were treated in exactly the same way.

The flies were bred in large cages in an artificially warmed room, under conditions known from long experience to be satisfactory for the production of healthy and vigorous flies. In order that perfect individuals for the experiment might be selected, the flies were placed in a refrigerator at about 2°C. for half an hour, after which they were sufficiently sluggish to be readily sorted.

For the main part of the experiment four constant-temperature waterbaths were used simultaneously, and they were maintained at temperatures with intervals of 10°C. After each day's observations the jars of flies were moved to the waterbath at the next higher temperature, and the flies that had been exposed to the highest temperature were destroyed, new flies being placed in the waterbath at the lowest temperature. The procedure ensured that:—

1. All the flies were exposed for at least twelve hours to the temperatures at which their activity was observed before any observations were made.
2. No fly was used for more than four days.
3. The species were compared simultaneously under identical conditions of light and humidity, as well as of temperature.
4. The effects (if any) of ageing were similar at all temperatures.

No apparatus was available capable of maintaining a temperature of 5°C. for any long period, so, in order to comply as nearly as possible with the above condition No. 1, half the flies were exposed overnight in the laboratory at about 10°C., the other half being kept in a refrigerator at 2°C. In the morning the flies were placed in a waterbath at 5°C., observation of their activity being commenced about an hour later.

Separate experiments at temperatures of 0°, 2°, and 5°C. were made immediately after the main experiments, using the special apparatus and methods already described.

The experiments were carried out in bright, diffuse light, which was tested at intervals by means of a photographic exposure-meter. With one exception the intensity of the light was found to lie within 16 per cent. of the median value. There was no direct sunshine.

No attempt was made to control or to record humidity. However, as all the species were treated in precisely the same way and simultaneously under identical conditions, all the species were subject to the same set of humidity conditions. It is probable that the presence of the water-supply vessel (fig. 1,s) caused the humidity to approach saturation-point.

In order to find whether activity is influenced by the sex of flies, or by the construction of the observation-jars in which they are examined, the sexes were observed separately, and two kinds of observation-jars (fig. 1, B and C) were used. The observations did not reveal any clear difference in the activity of the sexes, or in the activity of flies in the different kinds of observation-jars. Consequently the data obtained from all the observations of each species were amalgamated in the construction of the graphs used to illustrate the activity of the flies.

4. Results.

When compiling the records of activity all comatose and dead flies were naturally left out of account. Mortality, however, was very slight, except at the highest temperatures. The points shown in the graphs (figs. 2-8) are exactly as determined by the figures obtained in the experiments, no figures being discarded as "exceptional." The smoothness of the "curves" in these figures and the general similarity in the form of the activity-curves of the different species clearly indicate that the number of observations upon which they are based is adequate.

(a) General Activity.

In fig. 2 are plotted the results of the series of experiments in which the number of *L. cuprina* observed at a glance to be resting, "moving" or crawling was recorded. This figure shows that maximum activity occurs near the centre of the range of temperatures suitable for activity, and that "movement" begins at lower temperatures than crawling. It will also be observed that at 20°C. and less the proportion of "movement" to crawling is much greater than at higher temperatures.

This indicates that the amount of crawling is not directly dependent upon the amount of energy available but needs the stimulus of moderate or high temperatures. Consequently at moderately low and low temperatures energy is expended in fidgetiness, whereas at higher temperatures it is mainly expended in locomotion.

Graphs similar to those in fig. 2 were obtained for the remaining three species, and they all exhibit the features just mentioned. However, in order to compare the activities at different temperatures of the species examined, it has been found convenient to combine the data on which the "movement" and crawling curves are based. Moreover, instead of simply using the curves so formed, the maximum of the curve for each species has been taken as unity, so that the curves show the fraction of the maximum activity that takes place at any given temperature (fig. 3). In this way the slopes of the activity-curves are made comparable, so that the study of the differences between the species is facilitated.

The simple and regular form of the activity-curves in fig. 3 suggests that the activity of the flies is governed by some relatively simple physiological process.

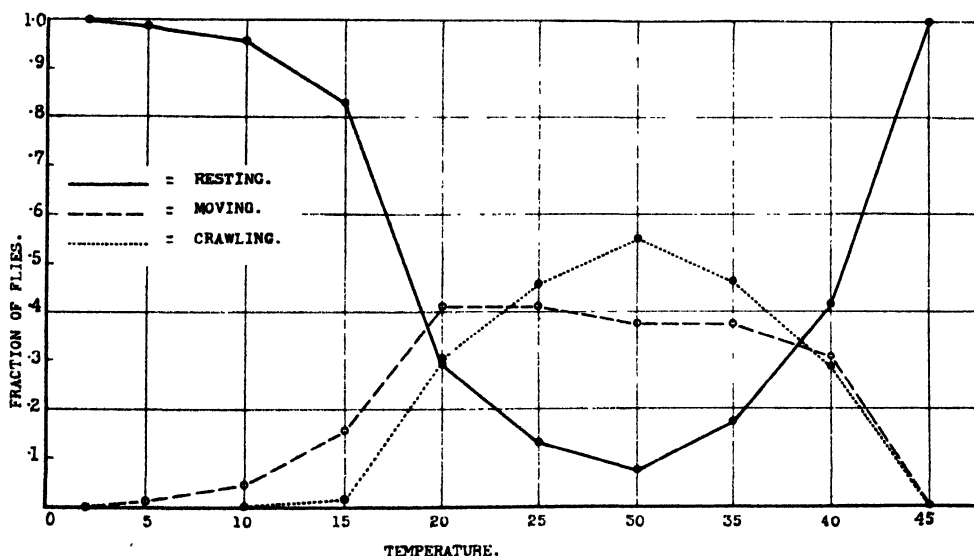


Fig. 2. Activity curves of *Lucilia cuprina* when subject to constant temperatures.

The morphological differences between *L. cuprina* and *L. sericata* are so slight that one can distinguish these species with confidence only after much practice, yet their temperature relations (fig. 3) are quite distinct, the zone of activity of *L. cuprina* being decidedly higher, and its zone of intense activity definitely narrower, than those of *L. sericata*. This lends point to the argument that the differences which have led to the evolution and separation of species may be inconspicuous ones which cannot be recognised by taxonomists when describing species. It may also be remarked that, although both species of *Lucilia* often occur in the same locality, *L. cuprina* essentially belongs to the warmer regions of this country and *L. sericata* to the cooler ones.

It will be observed that the zone of activity of *C. rufifacies* embraces the zones of the two species of *Lucilia*, which is also consistent with the known distribution

of the species. The zone of activity of *C. stygia* is decidedly lower than that of any of the other species. Observation in the field shows that *C. stygia* is essentially a cool-weather and southern species.

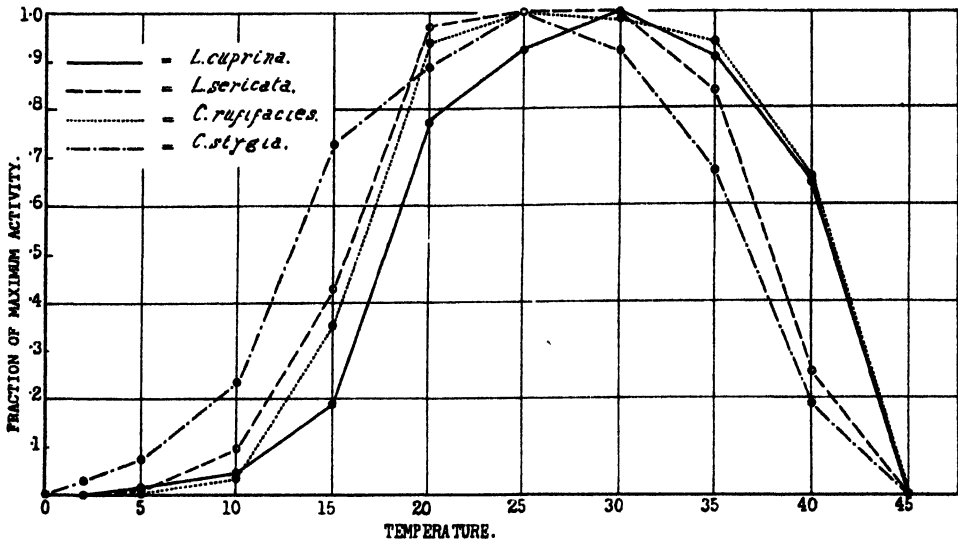


Fig. 3. General activity curves (combining "movement" and crawling).

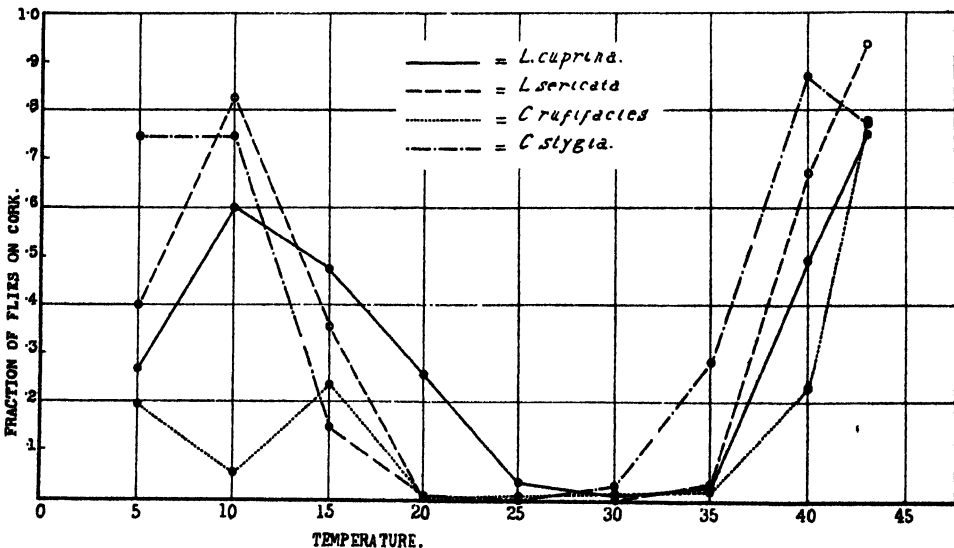


Fig. 4. Temperature-preference curves.

(b) Temperature Preference.

Fig. 4 shows the fraction of insects situated on the corks of the observation-jars at various temperatures, and it will be observed that this fraction is greatest near the extremes of temperature. It is unlikely that the air-temperature just below the cork differed much from that in the rest of the jar, so it is probably the warmer feel of the cork at very low temperatures and its cooler feel at high temperatures that attracts the flies.

The data on which fig. 4 is based give an independent corroboration of the temperature-relations of the various species exhibited in fig. 3. When few of the insects rest on the cork the temperature in the observation-jar may be assumed to be comfortable. It will be seen that the zone of comfort of *L. cuprina* is decidedly higher, and narrower, than that of *L. sericata*, that the zone of comfort of *C. rufifacies* embraces those of the two species of *Lucilia*, and that *C. stygia* shows a preference for a lower range of temperature than any of the other species.

The irregularities in the curves towards the extremes of temperature are probably due to the fact that here the flies are comatose, or nearly so. Consequently the flies are unable to reach the cork, although a position on it might be more comfortable than elsewhere.

The fact that a large fraction of *C. rufifacies* is present on the cork only at 43°C. suggests that flies of this species are less influenced by the temperature of the object on which they rest than are the other species. If so, this may well have an important influence on the proportion of the different species of flies caught in traps exposed to direct sunlight.

(c) *Regurgitation.*

While observing general activity, note was kept of all flies seen to produce "vomit" globules from the proboscis. The number of flies observed to do this was too small to permit of satisfactory graphical representation, so the records are given in the following table:—

Temperature	5°	10°	15°	20°	25°	30°	35°	40°	43°
<i>L. cuprina</i> ...	—	—	1	—	—	—	10	—	7
<i>L. sericata</i> ...	—	—	—	—	—	—	17	23	1
<i>C. rufifacies</i> ...	—	—	—	1	5	10	18	15	—
<i>C. stygia</i> ...	—	—	—	—	—	14	33	3	4

The figures are probably unduly small at the highest temperatures, for at these temperatures most of the flies were crowded on the corks in such positions that it was usually difficult to see their proboscises. Still, it is clear from the table that there is a definite association between the frequency of regurgitation and high temperatures. The reason for this association is not evident, but is it not possible that regurgitation, by increasing evaporation, may have something to do with the regulation of body-temperature? The habit of flies of swallowing the "vomits" and regurgitating them again after a short interval gives some support to this suggestion.

(d) *Flight Activity.*

The flies in each observation-jar were examined four times at each temperature, and each time the number of flights made in a period of one minute was recorded. Thus, the observations made of each species at each temperature are equivalent to the observation of a single individual for a period of two hours. The results of these observations are plotted in fig. 5, on the basis of the number of flights made on the average by a fly in the course of one minute.

The flight-activity curve of *L. cuprina* is almost symmetrical and of surprisingly simple form, and comparison with fig. 3 shows that the zone of flight activity corresponds almost exactly with that of general activity. The flight-activity curves of the other three species are not so simple, and the zones of intense flight activity of these species are all at higher temperatures than the maxima of general activity.

Although it is not yet possible to give a complete explanation of these facts, comparison of fig. 5 with fig. 3 is suggestive. The fact that the flight-activity curve and the general-activity curve of *L. cuprina* cover almost exactly the same zone, and have their maxima at the same temperature, indicates that the general conditions are suitable for the flight of this species, and that the amount of flight is directly dependent (or nearly so) upon the amount of energy available. On the other hand, the flight-activity curves of the remaining species suggest that the conditions are not altogether suitable for flight, and that the amount of flight lags behind the amount of energy available. This is not only indicated by the fact that the maxima of the flight-activity curves occur at notably higher temperatures than those of the general-activity curves, but also by the fact that the maximum flight activity of all these species is comparatively low. It seems probable that bright sunshine is the factor lacking, for *L. sericata* and *C. rufifacies* are known to be sun-loving species, while comparison of the curves in figs. 3 and 5 suggests that *L. cuprina* may be either a shade-loving species or indifferent to sunlight. If this is so, it gives a possible explanation of the great economic importance of *L. cuprina*, for under warm, moist conditions the fleece of sheep is most suitable for the development of blowfly maggots, and moist conditions are likely to be associated with dull weather. The unfavourable factor for *C. stygia*, however, is more probably the comparatively small space in the observation-jars for such large insects. It is hoped shortly to carry out experiments to determine the truth or otherwise of these suggestions.

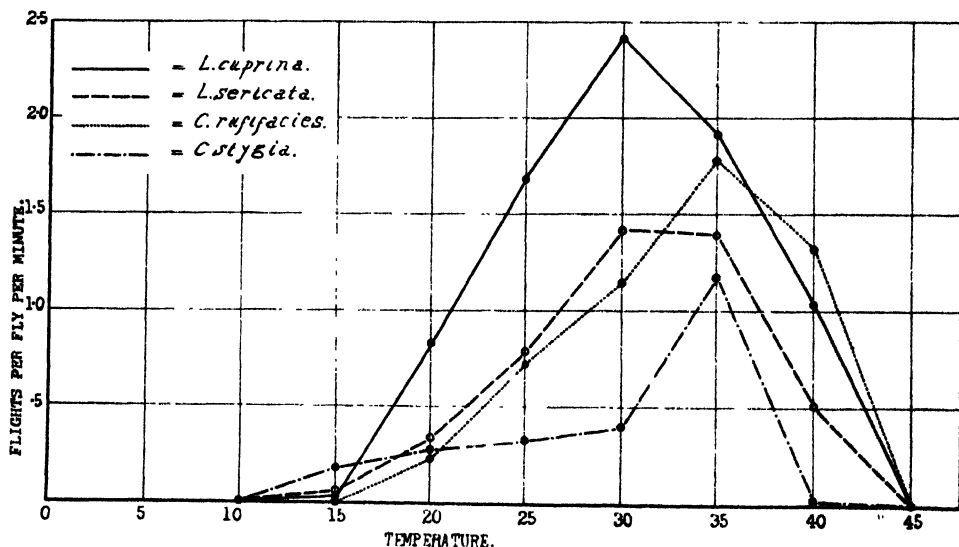


Fig. 5. Flight activity curves.

3. Experiment with Progressively Rising Temperature.

1. Apparatus.

The same apparatus was used for progressively rising temperature as for constant temperatures of 20°C. or more, except that a variable resistance was used in place of a thermostat. This consisted of a large glass jar containing water to which a minute quantity of caustic soda had been added, and in which two sheets of galvanized iron were suspended from glass rods. The rate at which the waterbath was heated was easily regulated by varying the distance between the sheets of galvanized iron.

2. Conduct of Experiment.

In this experiment *L. cuprina* alone was used. The flies, placed in observation-jars of the types used in the other experiments (see fig. 1, B and C), were kept overnight in a refrigerator at about 0°C. In the morning the jars were placed in a waterbath at 1°C. and the temperature was raised gradually, reaching 45°C. in approximately six hours. Five observation-jars, containing six flies each, were used, and five observations of each were taken at each temperature, *i.e.* only one-fifth of the number of observations made in the experiments with constant temperatures. The heating current was switched off for each set of observations, but because of the lag between the temperature of the waterbath and that of the observation-jars, the temperature continued to rise slowly while the observations were being made. For the record of flight activity, each observation-jar was observed for one minute at each temperature.

3. Results.

(a) General Activity.

The results of this experiment are plotted in fig. 6. Comparison with fig. 2 shows that the character of the relation between temperature and activity is quite different in the two figures. The small irregularities in the curves are probably of little significance. No doubt they are partly due to the comparatively small number of observations upon which each point is dependent, but there is reason to believe that they are mainly due to bursts of activity, similar to those which will shortly be shown to influence flight activity.

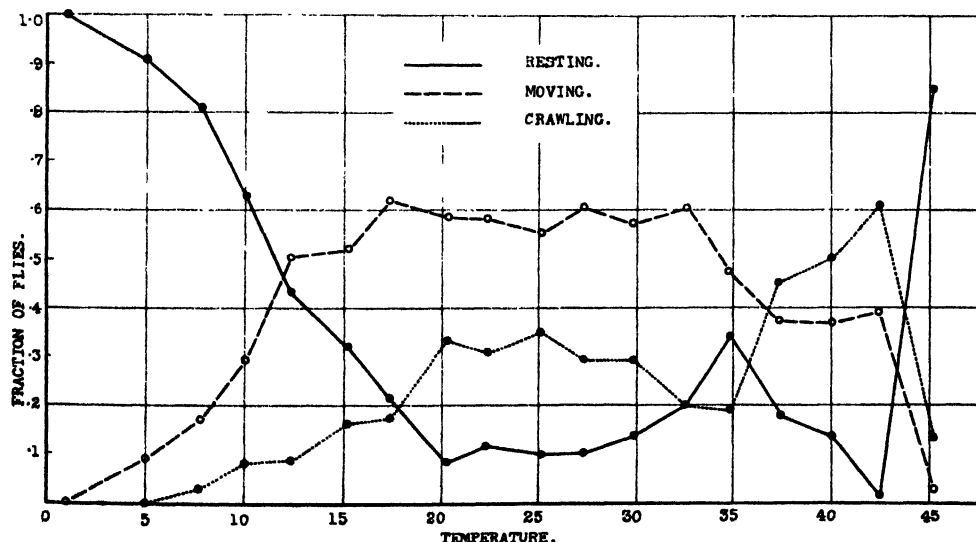


Fig. 6. Activity curves of *Lucilia cuprina* when subject to progressively rising temperature.

It will be noticed that the proportion of "movement" to crawling is greater in fig. 6 than in fig. 2, except at the highest temperatures. This suggests that, although rising temperature stimulates activity, the energy necessary for vigorous crawling at temperatures approaching the optimum is only developed by the flies after fairly long exposure to these temperatures. Consequently rising temperature produces fidgetiness rather than great activity.

In order to demonstrate clearly the differences in the activity of flies when subject respectively to constant and to rising temperature, general-activity curves (combining

"movement" and crawling) based upon figs. 2 and 6 have been superimposed in fig. 7. Up to 35°C. the form of the two curves is similar. This suggests that the same underlying physiological process that governs activity at constant temperatures also governs activity when the temperature is rising, but then operates over a lower range of temperatures. The small peak at 20°C. is probably of little significance. The curve indicates that this peak is due to a small burst of activity following a short period when the activity was a little less than it might have been.

At the lower and middle ranges of temperature, then, the character of the change in general activity of *L. cuprina* when the temperature is rising is similar to that occurring with a series of constant temperatures, but any given phase of activity takes place at a lower temperature. It may thus be said that rising temperature stimulates normal activity at temperatures below 35°C.

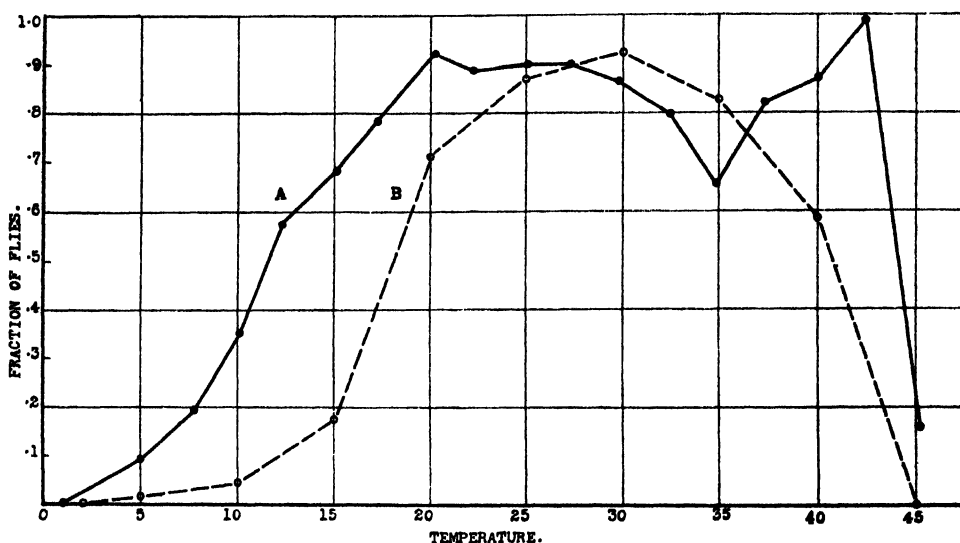


Fig. 7. *Lucilia cuprina*: a, general activity curve when subject to progressively rising temperature; b, general activity curve when subject to constant temperatures.

Above 35°C. the activity-curve for rising temperature is no longer similar to that for constant temperatures. In this region the activity progressively and rapidly increases until the temperature is a little below the upper thermal death-point, when the activity diminishes with extreme rapidity. The second zone of intense activity appears to be due to the distress caused by high temperatures. Probably the distress is similar at these temperatures when they are maintained constant, but after long exposure to a high temperature a fly no longer has the necessary energy for violent activity, while a fly freshly exposed to such a temperature has a reserve of energy which it expends in violent movement under the stimulus of great heat.

(b) Flight Activity.

The records of flight activity with progressively rising temperature are plotted in fig. 8, and for comparison the graph of the flight activity of *L. cuprina* at constant temperatures is shown in the same figure. The great difference in the relation between flight and temperature under the two given conditions is at once evident from this figure.

Unlike general activity, flight activity shows no sign of being stimulated by rising temperature. In fact, except at the highest temperatures, there is decidedly less flight with rising than with constant temperatures. The two peaks between 20° and 30°C. represent bursts of activity which are probably independent of temperature. When making observations of flight at constant temperatures, it was observed that the flies did not tend to maintain an average degree of activity, but had periods of intense activity separated by periods of rest. However, the great variations in flight activity observed at any given temperature cancelled out in the construction of the curves in fig. 5, owing to the large number of observations used. In fig. 8 the variations do not cancel, for with rising temperature all flies commence flight at the same temperature and time, and so the bursts of activity tend to coincide in all the observation-jars.

The general trend of the curve shows that frequency of flight tends progressively to increase with rising temperature. The activity increases very rapidly above 35°C., reaches a maximum just before the thermal death-point, and then decreases with extreme rapidity. Thus with flight activity, as with general activity, rising temperature causes the occurrence of distress activity between 35° and 45°C.

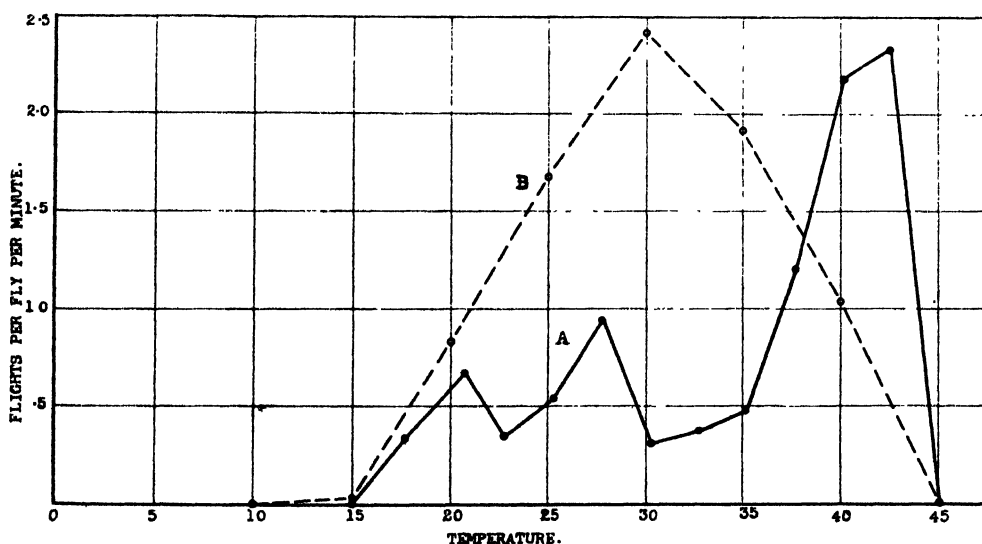


Fig 8. *Lucilia cuprina*: a, flight activity curve when subject to progressively rising temperature; b, flight activity curve when subject to constant temperatures.

4. Discussion.

It is of great interest to compare the results described in this article with those obtained by other workers. When studying activity, however, different investigators have examined several different processes, have measured activity in different ways, and have subjected the insects under investigation to temperature conditions that are by no means comparable. In the relevant literature available to the writer the following different ways of measuring activity are given:—

- (1) Intensity of metabolism (e.g. Cook (1927), production of CO_2 ; and Bodenheimer (1929), absorption of oxygen).
- (2) Velocity of locomotion (e.g. Miller (1929), blowfly maggots; Crozier & Stier (1925a), tent caterpillars; Bodenheimer & Klein (1930), and Stumper (1922), ants).

- (3) Proportion of time spent in activity (*e.g.* Bodenheimer & Klein (1930), proportion of nests of ants exhibiting each of four arbitrary degrees of activity; also present article).
- (4) Frequency of muscular contraction (*e.g.* Miller (1929), blowfly maggots; and Crozier & Stier (1925 and 1925a), various insects).
- (5) Arbitrary categories of activity-intensity in relation to temperature (*e.g.* Bodenheimer (1929), grasshoppers; and Chapman and others (1926), various sand-dune insects).

Added to the complexity of the ways of measuring activity is that of the types of temperature conditions to which the insects are subjected during observation. These are as follows:—

- (1) Constant temperatures (*e.g.* Cook (1927); and the present article).
- (2) Progressively rising or falling temperatures (*e.g.* Bodenheimer (1929); Bodenheimer & Klein (1930); Chapman and others (1926); and the present article).
- (3) Periodically fluctuating temperatures (*e.g.* Cook (1927)).
- (4) Very short exposures to given temperatures during observation, the insects prior to observation being kept at some arbitrary constant temperature, such as 0°C. or room temperature (*e.g.* Crozier & Stier (1925); and Miller (1929)).
- (5) Normal diurnal fluctuations of temperature (*e.g.* Bodenheimer & Klein (1930); and Stumper (1922)).

It is thus not surprising that it is difficult to compare the results of different investigators. It is quite clear, however, that activity is influenced not only by the prevailing temperature but also by the temperature conditions to which the insects were subject for some considerable period prior to observation (see Cook (1927) p. 769). This conclusion is strongly supported by the experiments described here (see figs. 7 and 8). It is evident, therefore, that the relation between activity and temperature is influenced by complex factors.

Moreover, it is clear that the character of temperature-activity curves is influenced, not only by the conditions to which insects are subject prior to observation, but also by the way in which activity is measured, and it is too much to expect any one formula* to describe all the different types of curves so obtained. For example, in the experiments here described, measurement of the proportion of time spent in activity gives curves (figs. 2, 3 and 5) with maxima not far from the centre of the temperature range, while observations during the experiments showed that movement *during periods of activity* progressively increased in violence with temperature almost to the upper thermal death-point.

Unfortunately it was not found possible to measure intensity of activity, but it is clear from what has just been said that if we could multiply the fraction of time spent in activity by the intensity of activity, curves would be obtained having maxima nearer the upper temperature limit than those shown in fig. 3. Such curves would resemble those obtained by Cook (1927, fig. 29) for CO₂ production at different temperatures. Both these types of curves at least approximately describe the relation between energy expenditure and temperature. Cook (1927 p. 777) has shown that there is a suggestive resemblance between such curves and curves illustrating the relation between temperature and the activity of enzymes, which

* Shelford (1929, p. 180) remarks "Crozier and others have been advocates of the idea that metabolic rates, growth rates, rates of locomotion, etc., conform to Arrhenius' formula and that each dominating reaction has a different constant. Thus, whenever the data do not fit the curve assumed, the constant is changed."

are explained as a result of "a balance between an increasing rate of activity on the part of the enzyme and a similarly increasing rate of destruction of the enzyme at high temperature."

Uvarov (1931, p. 59) concludes that "the rate of activities within the normal limits is not constant, but increases with the rising temperature." This conclusion was evidently based mainly upon the observations of Bodenheimer (1929) and Chapman and others (1926), which were qualitative observations of the activities of insects subject to progressively rising temperatures. Under these conditions activity does tend to increase progressively with temperature, as is shown by figs. 6, 7 and 8. If, however, the conclusion is intended to mean that the higher the temperature the greater is the activity, as is suggested by the context, it is difficult to reconcile with the results illustrated by fig. 3.

No one method of measuring activity can be considered superior to the others, for the method used must be determined by the particular aspect of activity it is desired to investigate. There seems, however, to be a general feeling that activity should be recorded in a way that has some relation to the rate of energy expenditure. Probably it was this feeling which caused Bodenheimer & Klein (1930) to make use of what they call the "activity index," which they obtained in the following way: They divided the degree of activity of ants about their nests in the field into four arbitrary categories, to which they gave the index-figures 0 to 3. By averaging the index-figures of the activity recorded in many observations at a given temperature, they obtained an "activity factor" for that temperature. It may be remarked that the graphs they obtained by plotting against temperature the fraction of nests at which activity of each category was recorded are similar to those in fig. 2. They also determined the number of seconds taken by ants to traverse a measured metre on a natural track and so found that there is a progressive increase of velocity of locomotion with temperature.* The "activity index" for a given temperature was then obtained by multiplying the "activity factor" by the velocity of locomotion. This gives some indication of the relative rate of expenditure of energy at compared temperatures, but the method is open to the serious criticism that the index-figures of the arbitrary categories of activity are used in the calculation as though they were quantitative data. Nevertheless, the "activity index" is the result of an effort to attain the ideal of taking into account both the fraction of time spent in activity and the intensity of activity during this time.

It is not only necessary to distinguish between the average expenditure of energy and the expenditure of energy during periods of activity, but also to recognise that expenditure of energy and frequency of muscular contraction are not necessarily directly related. From a study of *Lucilia* larvae Miller (1929) finds that the frequency of muscular contraction varies directly with temperature from 0° to 45°C., and that the height of contraction waves is constant between 10° and 33°C. but decreases outside these limits. Crozier & Stier (1925a) obtained essentially similar results when studying the peristaltic locomotor waves of caterpillars of *Malacosoma americanum*. Thus frequency of muscular contraction has a simpler relation to temperature than has energy expenditure, which indicates that speed of muscular contraction is governed by some simpler underlying process than is energy production. It would be of considerable interest to find whether frequency of muscular contraction is purely a function of temperature or is a resultant of temperature plus pre-conditioning effects, as is energy production.

* Uvarov (1931, p. 59) states that "Bodenheimer and Klein (1930), on the contrary, obtained a curve of velocities of running ants at different temperatures which is an equilateral hyperbola." This is clearly a slip due to the fact that the authors mentioned express "velocity" (Geschwindigkeit) in seconds per metre. By plotting the true velocity (in metres per second) against temperature the straight-line reciprocal of the equilateral hyperbola is obtained, which shows that, as usual, velocity increases with temperature.

A somewhat similar question arises from comparison of figs. 2 and 6 (see also fig. 7). With progressively rising temperature (fig. 6) the frequency of individual movements is decidedly greater than with constant temperatures (fig. 2) except in the region of 30°C., whereas, recognising that much more energy is expended in crawling than in making small movements, such as those of cleaning, the expenditure of energy is seen to be less with rising temperatures than with constant ones in the central region of the temperature range (between 20° and 35°C.). This suggests that muscular contraction is not wholly governed by the amount of energy available but is stimulated by rising temperature, which causes frequent small fidgety movements.

Moreover, the comparatively small expenditure of energy with progressively rising temperature in the central region of the temperature range suggests that the development of energy increases for some hours after exposure to these temperatures. This is consistent with the results obtained by Cook (1927, fig. 28) for the CO₂ production of cutworm larvae after exposure to constant intermediate temperatures for different lengths of time.

The great expenditure of energy in "distress activity" which occurs at rising temperatures (but not at constant ones) above 35°C. may be accounted for if we assume that insects have a considerable reserve of energy which is not called upon for normal activity, but which may be brought into use when the provocation is extreme. This is consistent with well-known human physiological phenomena and simply means that insects normally reduce their activity when a little fatigue is felt, but persist in activity up to the point of exhaustion under the stimulus of very high temperatures.

It is clear from this discussion that the relation between temperature and activity is so complex that, from its very nature, one cannot hope to describe it completely by means of a simple formula; nor can it be considered to be purely the expression of simple underlying chemical reactions.

5. Acknowledgment.

I am greatly indebted to Dr. M. J. Mackerras for the trouble she took in rearing the comparatively large numbers of healthy blowflies which were used in the experiments described in this communication.

6. Summary.

1. Quantitative methods of recording the activity of blowflies are described.
2. With constant temperatures the greatest activity occurs near the centre of the temperature range, whereas with rising temperature it immediately precedes the upper thermal death-point.
3. Rising temperature causes activity to occur at a lower range of temperatures than does constant temperature.
4. Rising temperature causes the appearance of "distress activity" at high temperatures, but constant temperature does not.
5. For the development of the necessary energy for full crawling and flight activity at the most favourable temperatures, rather long exposure to these temperatures is necessary.
6. Flight and, to a lesser extent, crawling occur in bursts of activity whether the temperature is rising or constant.
7. Differences in the reactions to temperature of the closely related species *Lucilia cuprina* and *L. sericata* are very distinct.

8. The curves for general activity and temperature preference correspond to the known distribution of the four species examined.

9. Frequency of regurgitation is definitely associated with high temperature.

10. There are strong indications that the conditions of the experiment were suitable for the flight of *L. cuprina* but unsuitable for that of the other species examined. This may have been due to the lack of bright sunlight, or to the confined space of the observation-jars.

11. It is shown that activity is a complex phenomenon, and that the character of the results obtained is influenced by the kind of activity examined, by the methods of measurement used, and by the nature of the temperature conditions to which the insects are exposed.

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OBSERVATIONS ON PHASES OF THE RED-WINGED LOCUST IN NORTHERN RHODESIA.

By A. P. G. MICHELMORE & W. ALLAN.

INTRODUCTION.

The present cycle of activity of the Red-winged Locust (*Nomadacris septemfasciata*) in Southern Africa commenced with the appearance of swarms in the vicinity of Mweru Marsh in North-Eastern Rhodesia. In 1929 definite swarms were present in the marsh, but small diffuse swarms or groups had been observed in the vicinity of the marsh during 1927 and 1928. There can be little doubt that these swarms originated from local breeding.

Until 1932 breeding took place in the more remote and, during the rains, inaccessible parts of the Protectorate, but in November of that year flying swarms invaded the settled area and there was extensive breeding within readily accessible districts.

The detailed observations on hopper development and phase colouring were carried out during the 1932-33 breeding season, extending from December until April.

In these notes the descriptions of phase *gregaria* and *dissocians* types of hoppers are most complete, for so far undoubted types of ph. *solitaria* have not been obtained; and although a considerable series of measurements of adults of the ph. *gregaria* has been completed, adequate material of other phases has not been available for comparison.

A. THE YOUNG STAGES.

1. Phase *gregaria*.

The Egg.

Shortly before hatching the egg is roughly cylindrical with pointed ends, and with the dorsal side slightly convex and the ventral side slightly concave except at the anterior end, where the deflected head of the embryo gives a convex surface to the egg. The length of the egg shortly before hatching is about 8.8 mm., and the greatest breadth 2.2 mm. (average of 5 measurements of preserved material). The same measurements for fresh eggs taken from the body of an ovipositing female are 6.3 mm. and 1.5 mm. respectively. The colour is pale brown.

The eggs are laid in clusters forming loose pods, cylindrical or fusiform in shape, wherein the eggs are arranged longitudinally like tiles on a roof with the head ends pointing upwards and inwards and the posterior ends downwards, overlapping the anterior ends of the lower eggs. The usual dimensions of the pod are about 3 cm. in length by a little over 1 cm. in breadth, and the average number of eggs in a pod is about fifty, though considerably smaller pods occur occasionally.

The Vermiform Larva.

The vermiform larva is pale brown in colour and of the usual Acridid type. Immediately after emergence from the egg the intermediate moult takes place.

The Structural Changes in the Nymphal Instars.

In *Nomadacris septemfasciata* there are six nymphal stages or seven instars including the vermiform larva. Previous authors have referred to the last two

stages as the fourth and fifth.* The stages are very readily distinguished by (a) the number of antennal joints, (b) the degree of backward prolongation of the pronotum and the development of the wing-pads, (c) the differentiation of the terminal abdominal structures, and (d) the measurements of the hard parts which do not grow between the moults.

(a) *The Antennae.*

The various joints of the antennae are differentiated in varying degrees. Mere enumerations of the number of joints give a wrong idea of the amount of variation, for the total number of joints may be a matter of opinion but the positions of the rudimentary sutures are constant. If the latter are given as well as the estimated total number of joints, the stage to which any hopper belongs may be recognised with certainty.

1st Stage.—Normally 13 distinct joints, of which numbers 6 and 7 are moderately and 2 and 8 more elongated. Eighth joint often with a more or less distinct division and the third joint sometimes similarly divided, then giving totals of 14 and 15 segments.

2nd Stage.—Normally 17 joints, of which numbers 7 and 8 are intimately and 9 and 10 less intimately connected; 11 and 12 occasionally show signs of more intimate connection than the following joints. Joint 5 occasionally and 6 fairly commonly divided more or less clearly, giving totals of 18 and 19 segments.

3rd Stage.—20 joints, with a trace of subdivision in the fifth and with joints 6 and 7 distinctly and sometimes 7 and 8 slightly more closely united than the following joints.

4th Stage.—22 joints, with 6 and 7 more or less closely united and the suture between them occasionally somewhat difficult to distinguish. Joints 8 and 9 sometimes rather more closely united than the following joints and 13 longer than its neighbours.

5th Stage.—Usually 24 clearly defined joints with often a more or less distinct division of joint 5. Joints 6 and 7 closely associated and the suture between them sometimes not clearly defined. Occasionally joints 8 and 9 are rather more closely united than the following joints.

6th Stage.—26 joints of which 4 and 5, 6 and 7 and to a less extent 8 and 9 are more closely united and shorter than the following joints.

The adult has 27 antennal segments.

(b) *The Pronotum and Wing-pads.*

The course of development of the pronotum and wing-pads is as follows (fig. 1) :—

1st Stage.—Hind margin of pronotum transverse with median emargination. Rudiments of wing-pads represented by rounding of the hinder margin of meso- and metanotum.

2nd Stage.—Slight backward prolongation of hind margin of pronotum, which has a median emargination. Wing-pads clearly defined as distinct lobes, demarcated from the tergites by a raised ridge and with traces of longitudinal striation and black streaking.

* Since this was written a description of the six stages of *gregaria* has been published. Messop, M. C. "Description of hopper instars of the red locust, *Nomadacris septemfasciata*, Serv., phase *gregaria*, and some changes in adult coloration."—Proc. Rhodesia Sci. Assoc. xxxii, May 1933.

3rd Stage.—Hind margin of pronotum with slight but distinct backward prolongation. Median emargination small or absent. Wing rudiments forming well defined triangular lobes pointing downwards and backwards.

4th Stage.—Hind margin of pronotum without emargination and prolonged backwards to cover the greater part of the mesonotum. Wing-pads larger than in the previous instar and still pointing downwards and backwards. Rudiments of wings twice as broad at the base as the rudiments of the elytra. Rudimentary venation conspicuous.

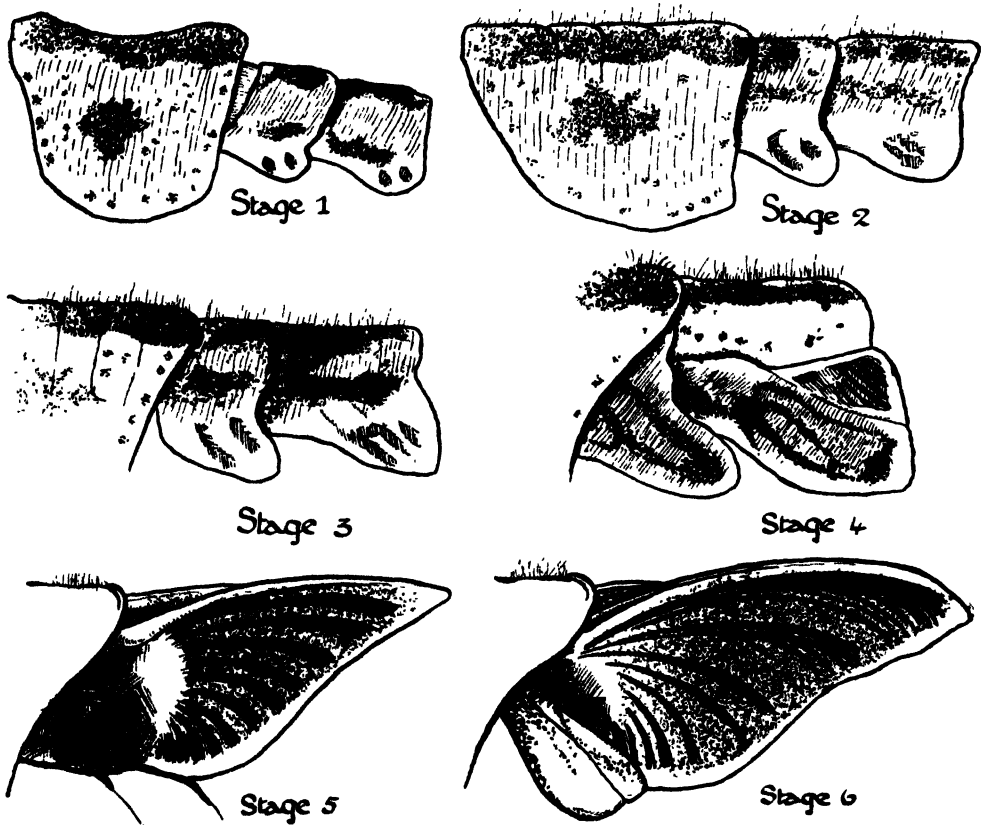


Fig. 1. Postembryonic development of wing-pads in the six larval stages of the Red Locust.

5th Stage.—Hind margin of pronotum with strong, rounded, backward prolongation. Wing-pads reversed, pointing upwards and backwards and about three-quarters of the length of the pronotum. Main veins clearly developed.

6th Stage.—Backward prolongation of hind margin of pronotum very marked. Wing-pads much longer than in previous stage, the length of the second pair exceeding that of the pronotum.

(c) *Terminal Abdominal Structures.*

These develop gradually during the nymphal life. Even in the first stage the sexes may be clearly distinguished by the presence of rudiments of the upper valves of the ovipositor in the female and of an unpaired plate forked at its hinder end in the male.

In the second stage the rudiments of the lower valves are visible in the female, while the unpaired plate of the male is altered in shape. The changes in the structures following each moult are figured (fig. 2).

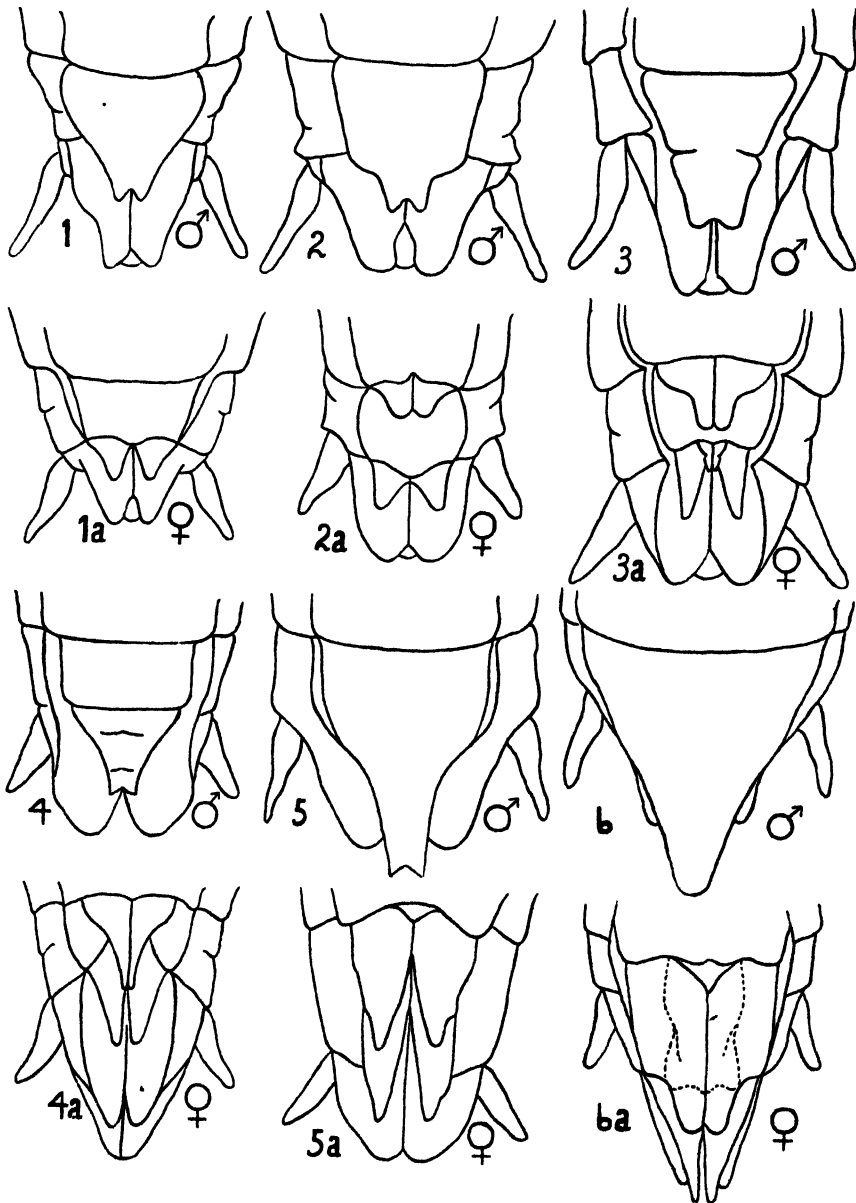


Fig. 2. Development of terminal abdominal structures in the six larval stages of the Red Locust.

(d) *Dimensions of the Hard Parts.*

Single specimens are sometimes difficult to place in their correct stage by eye alone, but the stages in a swarm can readily be separated by measurements of the hard

parts, especially of the head, prothorax and hind femora. The following table gives measurements of the length of the pronotum and femur for material taken from a number of swarms in the field. The measurements were made with a binocular microscope fitted with a squared eyepiece and travelling stage, so that it was possible to measure with some accuracy to the nearest tenth of a mm. The femoral measurements are based on 50 observations for each stage and the pronotal measurements on 25.

All material of the earlier stages from different swarms agree in the distribution of these measurements, but sixth stage hoppers derived from one large swarm at Lusaka (6a) gave ranges overlapping those obtained for fifth-stage hoppers from other swarms. It is therefore clear that the absolute measurements cannot be used for distinguishing the stages under all conditions.

In the last two stages the males are distinctly smaller than the females, and this is probably also the case in the earlier stages. Although separate measurements for the sexes have not been made, the plotting of one hundred femoral measurements for the third stage gave a curve of two maxima, indicating the possibility of difference even in this stage.

TABLE 1.
Length of Femur and Pronotum of Hoppers of the Red Locust ph. gregaria.

Stage	Length of Femur		Length of Pronotum	
	Mean	Range	Mean	Range
1	5.1 mm.	4.5-5.3	1.6 mm.	1.5-1.8
2	6.7	6.0-7.3	2.3	2.2-2.4
3	9.2	8.0-10.0	3.1	3.0-3.2
4	12.1	11.3-13.0	4.7	4.5-5.0
5	17.1	15.0-19.0	7.5	6.0-8.0
6	22.8	22.0-25.0	10.2	9.8-10.7
6 (a)	19.5	17.5-21.1	9.1	8.0-10.0

Colour Changes in Nymphal Instars.

1st Stage.—After the intermediate moult the hopper is at first uniformly pale yellowish brown except the eyes, which are reddish brown. Within probably a few hours the full colour pattern, which is as follows, develops. *Head.*—Ground-colour of head yellowish brown with dusky clouding and spots. Maxillary palps with the two proximal joints pale and the three distal joints black except base and tip, which are pale. First joint of labial palps pale, second pale with some black, distal joint mainly black but pale at base and tip. Base of mandibles pale, teeth very dark brown. Epicranium with an ill-defined pair of dusky stripes which converge slightly in front. Sometimes these stripes are obsolescent, sometimes spread out into a dark cloud extending down each side of the head behind the eyes and on to the genae. A conspicuous black triangular area with its apex directed downwards extends from the lower margin of the eye downwards and backwards across the genae. (In order to facilitate description this will in future be referred to as the genal stripe.) Antennal segments black with pale intersegmental rings. *Body.*—Pronotum pale yellow (Martius)* in ground-colour with broad, pitch black, dorsal, median band. Sides conspicuously marked with black dots, especially along the anterior and lower margins. An irregular or frequently roughly rectangular black area is present slightly below the middle of the side, varying in position and extent. (This will be referred to later as

* Ridgway. "Color Standards and Color Nomenclature." Colours obtained by comparison with this standard are marked with an asterisk.

the lateral pronotal blotch.) A black dorsal median band continuous with that on the pronotum extends across the meso- and metathorax and the abdomen as far as the ninth segment. The dorsal median band is bordered by a pale yellow line broadening on the meso- and metathorax. The lateral aspect of the abdomen is largely occupied by a broad, very dark brown band with sparse irregular whitish markings, which is narrowed on the first and sometimes on the ninth abdominal segment and extends to, but is narrowed on, the tergites of the meso- and metathorax. (It will be referred to as the lateral abdominal band.) A white line extends along the lower margins of the abdominal tergites. Thoracic pleurae pale yellow. Terminal abdominal segments yellowish, cerci black. Ventral aspect of abdomen and thorax brown. *Legs*.—Fore and mid legs dull yellow, with black spots, especially on tibia and tarsus. Claws and empodium black dorsally and yellow ventrally. Hind legs dull yellow with black dots. Incomplete very dark brown band on femur about three-fifths of the way from the base (referred to later as the hind femoral band), and sometimes an indication of an incomplete black band on the proximal border of the swollen tip of the femur which is testaceous. Tibia with numerous black spots on the outer surface, base and tip, and with a black line on the inner surface. Spines and spurs black. Tarsi, including empodium, mainly black above and yellow beneath. Claws black.

2nd Stage.—The general arrangement of the dark pattern of the body resembles that of the first stage, but a considerable difference in appearance is caused by the development of black pigmentation on the top and sides of the head and of an orange-red to testaceous colouring on several parts. *Head*.—Face orange-red, with black dots, especially on the keels. Centre of labrum and distal parts of exposed portions of mandibles and maxillae paler, sometimes with a greenish tinge. Maxillary palps pale orange-yellow, with joint 3 slightly and 4 largely black in the middle, especially above, and 5 completely black except for the pale tip. Labial palps with joints 1 and 2 pale, and 3 black except at the extreme tip. Epicranium entirely black, with this colour extending down over the genae and fusing with the genal stripe but leaving on the lower posterior corner of the gena a small triangular orange-red area, which is often continued as a narrow stripe round the back of the head. Genal stripe with a black, yellow border extending along its anterior edge from the anterior border of the eye just below the base of the antennae to the tip of the genal stripe; border broad above and tapering beneath and often interrupted or incomplete. Occasionally an irregular line of yellow dots marks the hinder border of the genal stripe, but the hinder border is well developed only in *ph. transiens*. Eyes mahogany-red, unstriped. Antennae mainly black, with basal joint and extreme base of second yellow. *Body*.—Yellow colour, brighter than in first stage (picric +). Dark markings similar except that all are black and that the lateral pronotal blotch is better developed. Meso- and metapleurae with a testaceous suffusion which extends to the wing-pads and often to the hinder and lower edges of the pronotum. Wing-pads with black longitudinal streaks. Lower surface of thorax testaceous and that of abdomen marbled dark brown on a pinkish ground. Tip of abdomen testaceous. *Legs*.—Fore and middle legs dull yellow. Coxae, trochanters and femora with testaceous suffusion and the black pigmentation of tibiae and tarsi more extensive than in the first stage. Hind legs bright yellow. Coxae, trochanters, bases of femora and sometimes tibiae with a testaceous suffusion; the broad femoral band black instead of dark brown, and the subterminal incomplete dark band generally more developed than in the first stage. Tip of hind femora of a brighter testaceous than in first stage. Hind tarsi completely black above.

3rd Stage.—These differ from the hoppers of the second stage in having the orange-red colour of the face richer. The underside of the thorax, tip of abdomen, hind femora, bases of cerci and the suffusion on the bases of the legs, are of a brighter orange-red colour, the suffusion on the leg-bases being also more extensive. The

antennae have the whole of the basal joint, the lower surface of the second and part of the lower surface of the third orange-red.

4th Stage.—The fourth stage resembles the third in all but a few details. The orange-red parts are of a slightly richer colour, which is a little more extensive on the bases of the legs. The antennae have the whole of the second joint except a dorsal black spot and much of the lower surface of the third joint red. The meso- and metapleurae are always suffused with testaceous, and there is a trace of yellow below the front wing-pads. The veins of the wing-pads are more clearly marked with black than before.

5th Stage.—This stage differs from the fourth in lacking the testaceous suffusion on the pronotum, wing-pads and meso- and metapleurae. The ground-colour of the pronotum is entirely yellow and that of the wing-pads pale yellow or whitish. The upper parts of the meso- and metapleurae are black. The cerci have at most only the distal half black.

6th Stage.—These closely resemble the fifth stage, except that the antennae have the basal third ventrally and the basal quarter dorsally orange-red. The epicranium is generally completely black or slightly brownish on top. The eyes sometimes have a trace of vertical banding, and only the tips of the cerci are black.

This stage has already been described and figured by Faurc¹ as the fifth stage. His description agrees exactly with hoppers seen by us in the field, except that in no case could the vertex be described as "tinged with orange" in what we consider to be the extreme swarm phase.

Changes in Appearance at the Moults.

On superficial observation it appears that there is a marked change in colour pattern at each moult, especially at the earlier ones. Apart from the change of colour of the head at the first moult, the alterations in colour distribution are actually very slight. The apparent great colour changes are due to the differential growth of the various parts of the body. The harder parts of the body, the head, prothorax and legs, only grow at the moult, and these are brightly coloured, so that a newly-moulted hopper is very gaudy in appearance. The dull-coloured abdomen, on the other hand, grows enormously between the moults, so that it comprises a larger and larger proportion of the surface of the hopper as each instar proceeds, until another moult readjusts the proportions. In the earlier stages, particularly the first, the stretching of the abdomen reaches such an extent before the moult that the body becomes transversely banded as a result of the exposure of the intersegmental membranes, thus presenting a different appearance from that of a hopper after the moult. At the beginning of each stage the tip of the abdomen falls short of the tip of the femur by the width of several segments; at the end of a stage it stretches several segments beyond the tip of the hind femur.

2. Phase transiens.

Hoppers known from their history in the field to have been definitely of the phase *dissocians* were studied in detail in order to provide data for comparison when undoubted types of *ph. congregans* can be obtained. Zolotarevsky² has claimed to be able to distinguish by their colouring hoppers of *ph. congregans* from those of *dissocians* in the case of *Locusta migratoria capito*, Sauss. Ability to distinguish the two forms would be of considerable practical as well as theoretical importance, but so far the finding has neither been confirmed nor disproved either in the case of *L. migratoria* or of any other species.

Coloration of Nymphs.

It will be convenient to analyse the components of the colour pattern and to indicate the colour changes in *ph. dissocians* as divergences from the *gregaria* pattern rather than to describe in detail the many types observed.

(a) *Eye Colour.*

The eye contains a mahogany-red + pigment and potentially bears a pattern of vertical stripes with one horizontal stripe above. The stripes are mahogany-red + on a pale ground. The pattern is distinct in all forms of ph. *dissocians* (and also in the adult of either phase); it is sometimes faintly indicated in the 6th stage nymph of ph. *gregaria*, but in all other stages of *gregaria* the red pigment is spread over the entire eye, effacing the ground-colour.

(b) *Dark Pigments of the Head.*

In ph. *gregaria* the dark markings of the head are black and most extensively developed. They show progressive reduction in various stages of *dissocians*.

The dark colouring of the antennae and palps is seen in the more advanced stages of *dissocians* to be primarily arranged in rings round the tip of each joint and to be most extensively developed on the upper surfaces and towards the apices of the appendages. In ph. *gregaria* the colour is black and extensively distributed, especially on the antennae, where very little of the ground-colour is visible, while in ph. *dissocians* the dark colouring tends to become reduced, especially at the bases of the appendages and of their individual joints, and to fade to a dark reddish brown.

The black of the epicranium and genae (excluding the genal stripe) is the first element of the colour pattern to fade under the influence of *dissocians*-producing factors. The black colouring fades first on an area on either side of the epicranium and recedes from behind forward, exposing a yellowish or reddish brown ground-colour. These areas join up and spread down the sides of the head. The most persistent parts of the black pattern are those adjoining the hinder yellow border of the genal stripe and the pair of punctured stripes on the epicranium. The black pigment of this element does not fade to brown.

The genal stripe is the most persistent element of the whole dark colour-pattern. Faure¹ shows (Plate xvi, fig. 27) a green hopper with the genal stripe narrow, but we have not observed hoppers in which the genal stripe was so much reduced. The genal stripe was always of full size, but in a few most extreme *dissocians* types there was a tendency for the black colour to fade to a very dark olive-green in the green hoppers and to dark olive-brown in the brown-suffused type.

(c) *The Yellow Border of the Genal Stripe.*

The yellow border is also very persistent in ph. *dissocians*. In ph. *gregaria* it is much encroached on by other colours, and the hinder border is not usually visible. It seems probable that it is masked by the other *gregaria* colourings and not really absent. When abutting on the black colouring of *gregaria* its outer margins are clearly defined, but in ph. *dissocians* it shades gradually into the ground-colour. In the most extreme *dissocians* forms the yellow border tends to become somewhat reduced and duller in colour. Although of the same hue as the yellow body-colour of *gregaria* the greater persistence of the yellow of the border of the genal stripe in *dissocians* suggests that it may be chemically different.

(d) *Ground-Colour of the Head.*

This is quite hidden by the black pigmentation in ph. *gregaria*, except in the first stage and sometimes when it is exposed to a slight extent on the epicranium in the sixth stage. In the earlier stages of *dissocians* the ground-colour is fairly constant in tint, but in the more advanced types it varies considerably. Generally the colour approaches the ground-colour of the body, but is always duller. Where the body-pattern is still more or less of the *gregaria* type, the head colour may be of different shades of dull yellow or brown, but in the green hopper it is usually green, and in the brown suffused type it is often dull yellowish brown suffused with olive-green or olive-brown.

(e) *The Orange-Red Colour.*

This colouring is an attribute of the swarm phase, being absent in the more advanced forms of ph. *dissocians*. In the second to the sixth stages of ph. *gregaria* it is present on the face, the tip of the hind femur, the tip of the abdomen, the under-side of the thorax and the bases of the legs. The colouring is most prominent on the face and tip of the hind femur, and least so on the bases of the legs. It increases a little in intensity during successive stages and is one of the first elements to change under the influence of *dissocians*-producing influences, beginning to fade as soon as the black of the epicranium is much reduced. On the head and tip of the femur it becomes duller, and in the final stages of its reduction it is represented only by a dusky clouding. On the thorax and legs the colour becomes paler and softer and takes on a more pinkish tinge before fading completely.

(f) *Dark Pattern of the Body and Legs.*

In ph. *gregaria* a large part of the body and leg surface is occupied by sharply defined black markings and scattered dots. In the middle stages of ph. *dissocians* they are considerably reduced in extent and in the more extreme stages they begin to fade away. Careful examination at this stage shows that the black markings become resolved into two components, little, dark, reddish brown spots similar to the dots which occur scattered all over the body surface, and a faint clouding of the same tint formed by minute speckling. It seems probable that there are three different black pigments in ph. *gregaria*, the slightly persistent pure black of the head, the moderately persistent pigment of the body, legs, antennae and palps, which look reddish brown when laid down thinly and black when dense, and the very persistent black of the genal stripe, which has a tendency to turn greenish in the extreme ph. *dissocians*.

The lateral blotch of the pronotum becomes somewhat reduced in size during the early *dissocians* stages but only breaks up and fades away completely in the more extreme forms. It includes some shallow depressions in the integument, which are often coloured greyish when the blotch is in the later stages of reduction. The dorsal stripe is one of the more persistent elements of the pattern. In all the forms which have been found it is clearly marked except at the hinder end of the pronotum, where it fades most readily. The lateral band is composed of round dots, cloudy suffusion, and dark patches occupying irregular depressions in the integument. Even in the most extreme *gregaria* forms a few spots of ground-colour show through the dark pigment of the lateral band. In ph. *dissocians* the band breaks up into its components fairly readily, especially along its upper edge, and it is also the first of these black markings to fade to brown.

The hind femoral band is a persistent element and fades to a dusky clouding only in the most extreme types. The other dark markings and dots on the legs, wing-pads and body gradually shrink during the early stages and fade to reddish brown in the extreme stages of ph. *dissocians*. The dark colouring of the wing-pad veins is the most fugitive. The ventral dark colouring is composed of a stippling or spotting of dark reddish-brown. In ph. *gregaria* it is often so dense as practically to obscure the pale ground-colour, but in ph. *dissocians* it becomes progressively sparser, though never absent even in the more extreme forms.

(g) *The Ground-Colour of the Body and Legs.*

This colouring is pale yellow in ph. *gregaria*. Occasionally it shows a trace of green colour towards the tip of the abdomen in types not far removed from ph. *gregaria*. Generally there is no change in body colouring, except a slight fading of the yellow, until the black of the epicranium and genae is completely reduced. In the more advanced forms of the "green type" every intermediate can be found between pure yellow and bright green body-colour. The green colour of the integument appears to be constantly associated with green blood, and with one exception all

hoppers with yellow ground-colour examined for this character had yellow blood. In the formation of the "brown-suffused type" of *ph. dissocians* there is a fading of the yellow ground-colour but no development of green.

(h) *The Brown Suffusion.*

It is curious that the dark reddish-brown suffusion and speckling of the thorax, which is a *dissocians* character in the last two stages, should be a normal variation of true *gregaria* in the second to fourth stages. In the more extreme forms of *ph. dissocians* developed in the absence of the factors producing the bright green coloration this suffusion becomes very marked and spreads over much of the body, sometimes including dull olive-green or olive-brown mottlings. It is then associated with an olive-brown or olive-green suffusion over the head.

Occurrence of Ph. dissocians in the Field.

The various forms of *ph. dissocians* observed in the field may be grouped into several types, the relationships of which are shown diagrammatically (fig. 3).

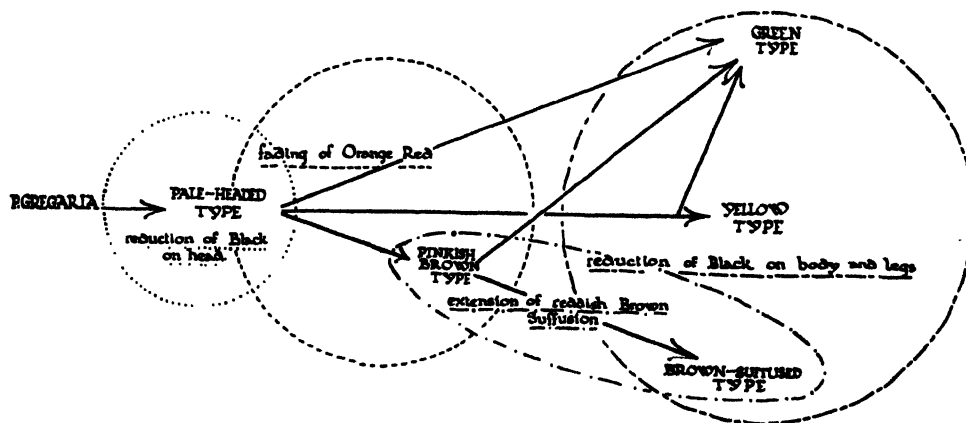


Fig. 3. Relationships of various colour types of hoppers of the Red Locust; phase *dissocians*.

The pale-headed type is the first stage in the production of *dissocians*. In the less advanced forms the only colour change is the reduction of the black colouring on the epicranium and genae, while in the more advanced types this is associated with some dulling and fading of the orange-brown and a slight reduction of the pronotal blotch.

The yellow type is produced by a further fading of the orange-red colouring and reduction of the black pigmentation on the thorax, abdomen and legs, so that yellow, fading progressively in the more extreme forms, is the dominant note of the colour pattern. This form is sometimes a stage in the formation of the green type but also exists as a distinct type, of which the more extreme forms are indistinguishable from the pallid type. It connects up with forms of the pale-headed type which have a pale yellowish or warm brown colour on the head.

The brown-suffused type usually follows on the pale-headed type, after most of the epicranial black has gone, and shows the same variation in the ground-colour of the head. In its early stages the type is characterised by fading of the orange-red and partial change of it to a pinkish tint, by extension of the reddish brown suffusion especially on the hinder part of the pronotum, by the fading of the black wing-veins to a reddish brown, and sometimes by a development of pink in the ground-colour especially of the hind tibiae, metanota and metapleurae. The lateral pronotal blotch, posterior quarter of the dorsal median band of the pronotum, black markings

of the abdomen, and hind femoral band, may be somewhat reduced or faded. The yellow ground-colour is generally a little faded. In the more extreme forms of this type the ground-colour remains pale yellow but is largely hidden by the extension of the reddish-brown suffusion. The body markings, though generally not greatly reduced, are considerably faded. Forms of this type found in the field all connect up with pale-headed types having a dull brown ground-colour of the head.

The green type appears in the field to have been chiefly derived through the earlier stages of the brown-suffused type and to some extent direct from the pale-headed type, with only slightly reduced body-markings. It can also be related to the yellow type with reduced body-markings. In this type the head and body ground-colour is green with subsidiary yellow and dark brown markings. Sometimes types occur in which the epicranium is pale brown or the face orange-brown. The latter form agrees with the type of hopper found by Lean⁸ forming swarms by Lake Chad. In the more extreme forms of the green type the black pattern is very much reduced.

A detailed study of the ph. *dissocians* was made in the Chisamba area, where at the beginning of the season only the ph. *gregaria* was present and where the swarms were broken up by intensive control measures. Forms of the ph. *dissocians* first appeared in the second and third stages where swarms had been heavily poisoned in the late first and second stages. These forms appeared only four days after the commencement of destructive operations, indicating that hoppers of this species are very sensitive to *dissocians*-producing influences. This indication is borne out by all other observations both in the field and in cages. At the time of the first appearance of *dissocians* moulting of first and second stage hoppers was taking place, and the colour changes appeared to have occurred at the moult. At first practically no *transiens* forms could be found except where swarms had been poisoned, showing that they must have been derived from ph. *gregaria*. The exceptions were a few individuals of the green type probably isolated since hatching and picked up by swarms. The earlier forms of *dissocians* to appear were all, apart from the few exceptions mentioned, of the pale-headed type. Later, early stages of the brown-suffused type and of the green type appeared in increasing numbers and with increasingly large proportions of the more extreme forms, showing that the direction of change was actually that described (fig. 3). Only in the last two instars did hoppers of the extreme brown-suffused and yellow types become common.

The brown-suffused type first appeared on the margin of a large expanse of bare ploughed land into which movement of *dissocians* forms was taking place. At the very end of the season, when the grass was drying up owing to early cessation of the rains, they appeared in other parts.

Throughout the farming area similar changes in the colouring of *dissocians* hoppers were observed. This area consists of a narrow belt extending northwards along the railway line. The southern part consists mainly of *Brachystegia-Isobertlinia* forest with short grass and light sandy soils. The central Mazabuka area consists of sweet thorn bush (*Acacia* spp.) with long grass and heavier loam soil, and the northern area of transitional bush with fairly long grass. The extent and duration of the rains increase from south to north, the annual precipitation being highest at Chisamba. The period of rainfall extends normally from November until March but during the season of observation rainfall was abnormally low throughout the farming belt.

In each area the more extreme forms of *dissocians* encountered in the first three or four stages were entirely of the green type. The change in the ground-colour and the appearance of yellow and brown-suffused types coincided with the fading of the grass following the cessation of the rains. Green types disappeared earliest in the south but were present in the Chisamba district until late in the season.

Several cases were observed of small bands of hoppers at first showing true *gregaria* colourings receding to *dissocians* later without any disturbing human influence.

This suggests either that *gregaria* colours are inherited by the earlier instars or that a greater degree of crowding is necessary to produce *gregaria* colouring in the later than in the earlier instars.

Similar recession on a large scale occurred in the Machili River valley in 1931. In December of the previous year eggs were laid over a wide area by the first migratory swarms to enter north-western Rhodesia. The earlier colourings are not known, but in their last two stages all hoppers ranged from forms of the more extreme pale-headed types to yellow types with much reduced black body-markings.

A possible Occurrence of Ph. congregans.

Nomadacris septemfasciata is apparently a permanent inhabitant of the wide alluvial grasslands of the Kafue Flats. In this area undoubted *transiens* forms were present before the appearance of swarms within several hundred miles. Owing to the flooding of the Flats, hoppers of the earlier stages could not be obtained from the field, but in their later stages they were indistinguishable from hoppers of *ph. dissocians* of the extreme pale-headed or less extreme yellow types with somewhat reduced black markings, especially in the case of the pronotal blotch, hind femoral band and lateral abdominal band.

Cage Experiments.

The cage experiments described were carried out in the season 1932-33. In all cases hoppers were fed on the natural veld grasses, fresh grass being cut and placed in the cages twice daily. Except in the case of cage 3 the old grass was not removed and the space occupied by the hoppers was to some extent reduced continuously. The material consisted of the progeny of swarms and of *transiens* (probably *congregans*) types from the Kafue Flats. An endeavour was made to rear both types under crowded and uncrowded conditions.

(a) Effects of Crowding.

Cage 1. Approximately 5,000 first stage hoppers, progeny of very small loose flying swarms, were taken in the field and confined in a cage 21 ins. square and 33 ins. in height. Crowded conditions were maintained throughout. From the second to the fourth stage the colouring was typical of *gregaria* but in the fifth stage the black of the epicranium tended to fade. In the sixth stage in practically all cases the upper part of the epicranium was tinged with brown, and the posterior yellow border of the genal stripe was always well developed.

Though a certain amount of development of these characters is regarded as normal variation of *gregaria*, the adult forms obtained could not be referred to the extreme swarm type, and it is probable that the sixth stage hoppers represented early forms of *dissocians*.

In the field all individuals of the swarm from which the material was taken receded to *dissocians* forms of the extreme pale-headed type.

Cage 2. A hundred pairs of adults taken from the Kafue Flats were placed in a similar cage in the expectation that their progeny would be sufficiently numerous to produce crowded conditions.

Copulation was first observed on 29th November, and the first eggs were laid about the 10th December, hoppers emerging early in January. By 6th January all adults in the cage had died, but hopper emergence continued until the third week of February. Owing to a poor hatching, spread over a period of about six weeks, densely crowded conditions were never attained, the maximum number of hoppers being in the neighbourhood of two hundred. By 19th March the first hoppers to hatch were in the 6th stage. These, which were at first of green or yellow *dissocians* forms, were then of a less extreme brown-suffused type.

The later hatchings reached the sixth stage about the middle of April, and though they had experienced more crowded conditions from the beginning than the earlier hatchings, the majority could be referred to more extreme forms of *ph. dissocians*. The black markings were considerably reduced, the pronotal blotch being absent. The ground-colour was faded to a greenish or yellowish grey somewhat suffused with brown, except in the case of the abdomen and the border of the genal stripe which were pale greyish yellow. It is necessary to observe that during the last two stages and in some cases part of the fourth the later hoppers experienced relatively low temperatures and showed very little activity, remaining for the most part stationary against the netting of the cage, while in cage 1 there was very marked activity throughout the period of development.

(b) *Effects of Uncrowded Conditions.*

Cage 3. A few egg-pods laid by a swarm in the field were placed in a cage 24 inches square and 15 inches in height, and with some 3 inches of earth in the bottom. The earth was not covered with grass and represented the greater part of the background. Eleven hoppers only emerged and remained uncrowded throughout development. At all stages in which they were examined the hoppers could be classed as extreme forms of the brown-suffused type.

Cage 4. This cage measured 33 ins. square by 45 ins. in height and in it 10 pairs of adults from the Kafue Flats were placed. Although the adult material was derived from the same source as that in the cage (No. 2) intended to be crowded and conditions in the two cages were similar, emergence in the uncrowded cage was completed during the first fortnight of January. Crowding was very slight, some 50 nymphs only being obtained, and the material was very uniform for stage of growth throughout development. Hoppers were at first green with well developed black markings. The black of the epicranium was represented only by the two converging lines of black dots, but the lateral pronotal blotch, hind femoral band and black pigmentation of the lateral abdominal band were well developed. Between the second and fourth stages a colour change took place, and in the fifth and sixth stages the body was yellow with a slight reddish-brown suffusion extending over the posterior quarter of the prothorax.

In the case of Cage 4 the greater part of the background consisted at first of green grass placed in the cage and latterly of dry yellow grass, the colour change being associated with the fading of the grass. The observations indicate that hopper colouring is, at least in some degree, associated with the colouring of the environment.

The dependence of the development of swarm colouring on activity rather than any other factor associated with crowding is also indicated. This was most clearly demonstrated by the results obtained in Cage 2, wherein the later hatchings, although more crowded than the hoppers in Cage 4 could be referred to more extreme forms of *ph. transiens* apparently on account of the lower temperature conditions which they encountered during development. The impossibility under cage conditions of obtaining intense activity such as occurs in the field may account for the failure to obtain extreme swarm types even under very crowded conditions.

(c) *Relative Effects of Isolation on gregaria and transiens Hoppers.*

In order to determine the relative effects of isolation on *gregaria* and *transiens* hoppers three individuals in the second stage showing pure *gregaria* colouring were taken from Cage 1 and three green forms in the second stage from Cage 4. These were isolated in small glass-fronted wooden cages, measuring 9 ins. by 6 ins. by 6 ins., for the remainder of their development. In each case colour changes, accompanied by reduction of the black pigmentation, were obvious after the first moult in the isolation cage. In the sixth stage these individuals showed characters of the extreme brown-suffused type with reduced black markings, the lateral pronotal blotch being absent, while the black of the lateral abdominal band was reduced

and faded and the hind femoral band represented only by dark clouding. The yellow of the pronotum was considerably faded. It appeared that the black pigmentation was only slightly, if at all, better developed in the forms isolated as typical *gregaria* individuals.

It is therefore indicated that *gregaria* individuals show no inherent tendency to retain the swarm colouring but react as readily to *dissocians*-producing factors as individuals of the *ph. transiens*.

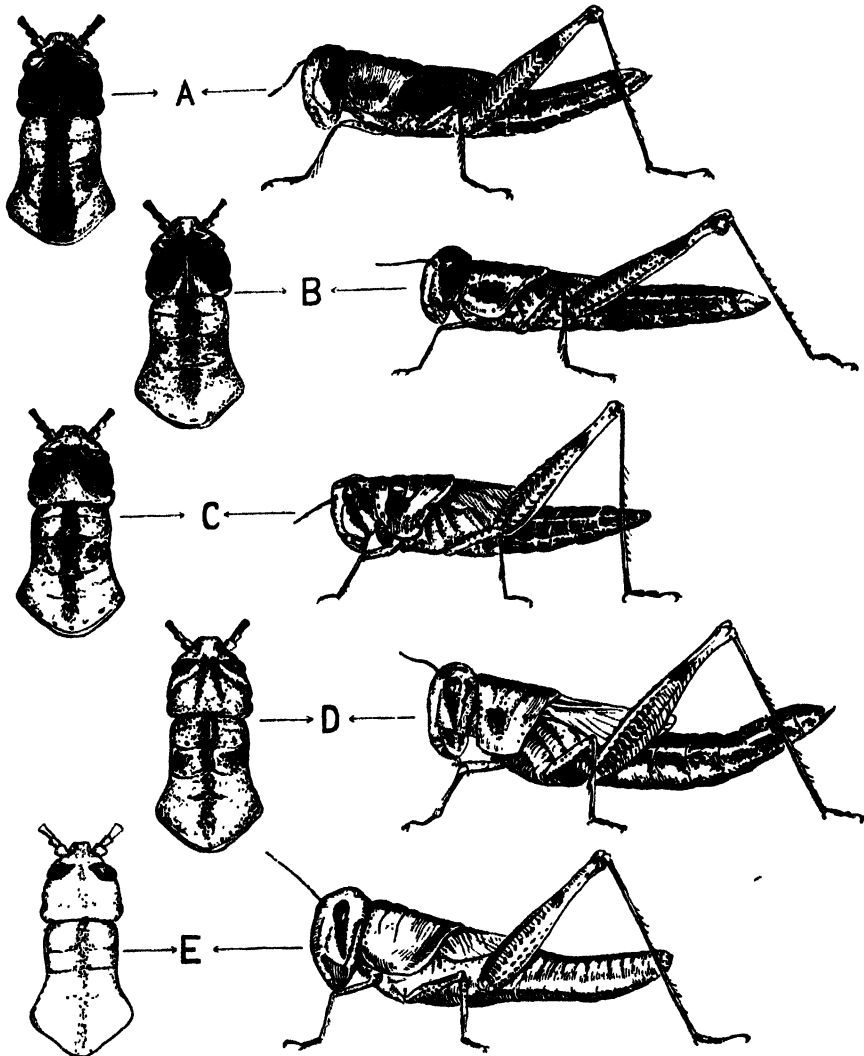


Fig. 4. Reduction of black pigmentation in phase *dissocians* hoppers of the Red Locust :
a, phase *gregaria* ; b-d, phase *dissocians* ; e, pallid type.

(d) *General Considerations.*

These observations confirm and supplement Faure's experimental work.¹ It has been strongly indicated in the field that the green colouring of *dissocians* hoppers

is associated with high humidity conditions and the presence of green food, while other colourings are at least in some degree influenced by the colouring of the environment.

It is also strongly suggested that activity is the factor in crowding influencing the production of *gregaria* colouring. In the field no difference could be observed between the behaviour of differently coloured hoppers. Extreme *dissocians* types caught up in swarms behaved exactly like *gregaria* hoppers, while extreme swarm types left isolated from swarms behaved like *dissocians* individuals.

The only observation not entirely in accordance with this supposition was derived from the experience of one of us (W. A.) in the Lusaka district. Here a large swarm some fifteen miles in length and from two to five miles in depth advanced a distance of at least 20 miles into the farming area, moving latterly at the rate of almost a mile a day. An intensive campaign against this swarm broke it up into many smaller swarms, but these remained dense and apparently did not abate their activity. In the fifth stage the epicranium was completely black, but in the sixth about half of the hoppers showed a distinct paling on top of the head. In the Chisamba area it was observed that all swarms in the uninhabited bush, however small in size and however slowly they moved, were composed in the last stage entirely of black-headed hoppers. On a farm two small swarms were observed which showed a similar slight paling of the top of the head in a considerable proportion of their members, but at the time this was explained by a slight scattering produced by the configuration of the ground across which they moved. In view of the Lusaka observation it must be assumed that some degree of paling of the head is a normal variation of the extreme ph. *dissocians*, and that there may be some factor modifying the main one of activity which influences the colouring of the hopper.

3. The Pallid Type of Hopper.

Description.

A curious type of hopper was found during the 1932-33 breeding season in the Chisamba farming area. The general impression of the colour of this type is of a dirty yellowish brown, but careful comparison shows that the ground-colour is often just as bright yellow as in extreme ph. *gregaria* hoppers, though sometimes it is paler. The apparent dullness is caused by lack of contrast with the dark pattern, which is much reduced and faded. The ground-colour is often tinged with green round the mouth and anus. The orange-red colour and the black face markings of ph. *gregaria* are faded to reddish brown, which in places is still so dense as to be almost black and elsewhere quite pale. All the black markings are reduced in extent and faded to reddish brown except the genal stripe, which is of normal size and blackish brown. The dark pattern is reduced to about the same extent as in the most extreme forms of ph. *dissocians* described above, and the different elements show the same differences in the degree of reduction. The dark markings of the body and legs similarly tend to be resolved in varying degrees into their two components, a clouding formed of almost microscopic speckling and dots, which often have pale centres and surround the bases of hairs. There is no development of the brown suffusion. The eyes are not banded. As the eyes were not examined in living specimens, it is not possible to state their colour, but from preserved material it appears that they are dark brownish red as in ph. *gregaria*.

Occurrence and Origin.

The pallid type was first observed in the third stage. It appeared in small numbers in each succeeding stage and only after a considerable portion of hoppers had reached the stage in question. The pallid form soon became fairly common on several farms but was not found in the bush outside. This may, however, be accounted for by the greater amount of time spent in observations on the farms. Though sometimes

wandering with swarms, hoppers of the pallid type were mostly to be found among scattered individuals left in cultivated lands by the advance of swarms and by the control measures of farmers. In many cases it was observed that pallid hoppers were sluggish and easier to catch than the normal hoppers.

At first there were no intermediates between the pallid type and the *gregaria* and *dissocians* types present, indicating that the change from *gregaria* or *dissocians* to pallid colouring must take place suddenly and therefore presumably at a moult. In the last three stages some of the types of *dissocians* found in the field approached the pallid type so closely that it was impossible to draw the line between them. In one case a yellowish green sixth-stage hopper produced several Dipterous parasites, and during the few days for which it survived after the emergence of the parasites the green gradually faded until the hopper showed typical pallid coloration. This observation is of interest in showing that the ground-colour may fade without a moult, but it is unlikely that this is the case with the dark markings.

A great many hoppers of the pallid type were pulled open, and in the majority of cases they contained Nematode worms from 6 to 10 inches in length. Normally only one worm was present in each hopper, but occasionally there were two. In the case of the few hoppers which the limited accommodation available allowed to be kept it was found that the worms eventually emerged, and the hoppers, which were by then very sluggish, survived the emergence for a day or two and then died. This may explain the occurrence of apparently unparasitised hoppers of the pallid type.

Hoppers of this type were occasionally found containing one or more Dipterous larvae with or without a worm in addition. The proportion of pallid hoppers containing Dipterous larvae was not appreciably higher than that of the *gregaria* and *dissocians* type containing them, and it is therefore uncertain whether these parasites can cause the pallid coloration, or whether the presence of a Nematode is necessary. Similar Nematodes were frequently found in hoppers with *gregaria* and *dissocians* colouring, but in these phases, unlike the pallid type, parasitised individuals formed only an infinitesimal portion of the total number of hoppers and were found mostly as stragglers in cultivated lands. If the theory that change from the more heavily pigmented to the pallid type can only take place at a moult is correct, it may be supposed that such hoppers had not moulted since the parasite became sufficiently developed to cause much change in metabolism and colour production. This suggestion is supported by the finding of some of these hoppers in which distension of the abdomen and hardening of the head-capsule was even more marked than usual in hoppers about to moult, indicating that the presence of the parasite might have prevented the moult.

The evidence collected in the field indicates that the pallid type of coloration described is probably caused by the presence of Nematodes and possibly also by Dipterous parasites. Discordant factors are the occurrence of parasitised hoppers without pallid coloration and of unparasitised pallid hoppers. Although the presence of such forms can readily be explained by the theories given above, the matter is still open to some doubt until the pallid coloration is produced by experimental parasitism under controlled conditions.

Harris⁴ has recorded a distinct change in the colour of fifth-stage hoppers of *Locusta migratoria migratorioides*, R. & F., infested with *Mermis* in Tanganyika.

Inferences regarding the different Processes in the Formation of the Nomadacris Colour Pattern.

Some conclusions bearing on the physiology of the colour patterns can be inferred by considering the pallid and *transiens* types together. The matter is evidently more complicated than a mere reversible change determined by the balance between

what may be called "*gregarians* factors" and "*dissocians* factors." The different reactions to the *dissocians* factors and the "parasitic factors" shown in the pallid type indicate that the colour patterns fall into at least three physiological groups. Considering changes away from the *gregaria* type we see that the ground-colour is affected little by the parasitic factors and much by the *dissocians* factors; the eye colour is apparently not changed by the former but is altered by the latter; the dark pattern and the orange-red pigment are strongly affected by both but especially by the parasitic factors. The similarity in the relative degrees to which the various dark markings and the orange-red colour are reduced in the pallid and extreme *dissocians* types suggests that all these elements are produced by closely allied processes. For instance: the lateral pronotal blotch shows more tendency to disappear than the abdominal part of the dorsal stripe both in the pallid and in the *dissocians* type. It is therefore likely that the physiology of the production of these and other elements is the same, and that the processes only differ in intensity in different parts of the body. As shown above (p. 108) the epicranium and the genal stripe behave differently from the other dark markings under the influence of *dissocians* factors, and may constitute two more physiological groups in the colour scheme. The yellow border of the genal stripe also seems to differ from the ground-colour, forming a sixth group. In certain stages of reduction the orange-red, the dark colouring of the body and appendages, and the brown suffusion, all have a very similar tint, and it is not improbable that they consist of almost identical pigments.

B. THE ADULT.

1. Colouring of *Ph. gregaria*.

(a) *Young Adults*.

The following description is of the young adult a few days after the ultimate moult, at the time when the integument first becomes hard and it is able to fly strongly. Immediately after moulting the colours are pale, but in two or three days the shades described below develop. Although subsequent changes take place, the stage here described may be considered as marking the attainment of bodily, but not of sexual, maturity. At this stage the young adult resembles that shown in Faure's figure (Pl. xvi, fig. 33) on the whole, but the markings are more clear cut and the light parts paler.

Head-capsule. Face, mouth-parts and lower and hinder corner of gena orange or reddish orange with dull greenish-brown clouding on the facial keels, a central strip down the clypeus, labrum and mandible. Mandible with two whitish or pale yellow keels. Epicranium with a broad, median, whitish or pale yellow stripe. Remainder of epicranium and most of genae entirely olive-green or olive-brown or olive-green at the front and sides and olive-brown at the back and towards the centre. Genal stripe and its pale borders complete, as in the *transiens* hopper, the former being dark olive-green and the latter whitish or pale yellow. Eyes with the same pattern as in the *transiens* hopper, the dark red bands being broader than the pale red spaces between. *Antennae* 27-jointed; the basal one or two joints orange, paler above than below; remainder of basal third of antennae pale yellow, shading into the dusky apical two-thirds, the joints becoming progressively darker from base to tip; the partly dark joints each have a dark ring round the tip, as described for *dissocians* hoppers. *Maxillary palps* 5-jointed, 1st and 2nd joints orange-yellow 3rd orange-yellow or pale yellow with some dusky clouding towards the tip, 4th with the basal third pale yellow and the distal two-thirds dusky, 5th with the extreme base pale yellow and the rest dusky. *Labial palps* orange-yellow, with the apical two-thirds of the last joint dusky.

Pronotum with a broad, median, creamy white stripe continuous with the one on the head. On either side of this a broad, dark red band, separated from the

white by a more or less complete, narrow, blackish stripe. Below the red a broad belt of creamy white with pale bluish grey or brown patches and with the posterior two-fifths more or less suffused with orange or red, but never to such an extent as entirely to hide the pale band, as in Faure's figure (Pl. xvi, fig. 33). Below this again another dark red band, broader behind than in front. Below this another creamy white area at the bottom edge of the pronotal flap. The entire pronotum completely surrounded by a raised rim of creamy white colour. Most of the hairs arise from little creamy white dots, some of which are enclosed in small round black or bluish grey spots. *Mesonotum* pinkish white. *Metanotum* brownish in centre, whitish at scales, with some of the raised ridges black. *Meso-* and *metapleurae* with pattern of raised, olive-green or brown reticulations enclosing yellowish punctures and with some white dots.

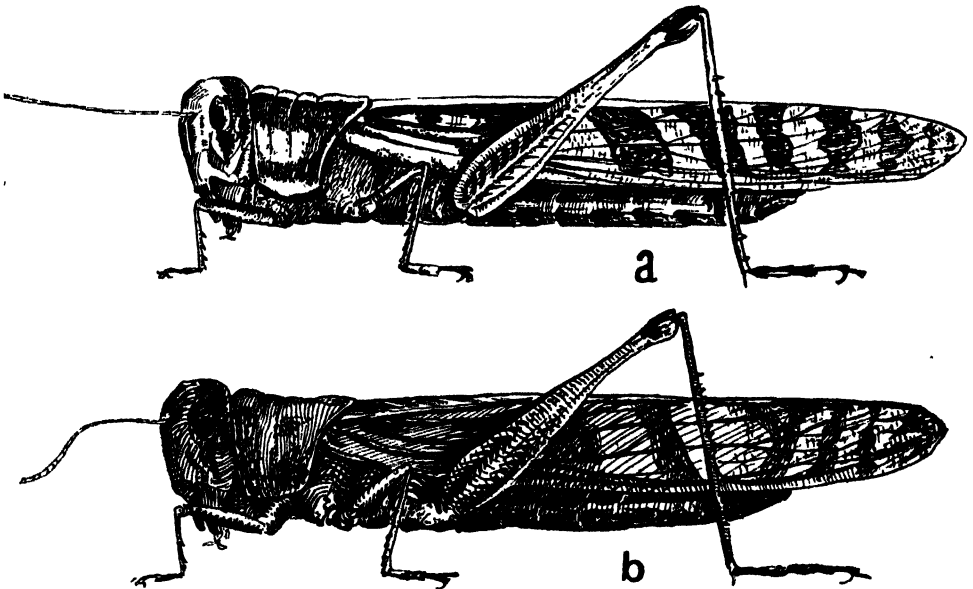


Fig. 5. Adults of the Red Locust : *a*, young adult a few days after the ultimate moult ; *b*, taken from a large swarm in August.

Tegmina. General appearance creamy white fading to nearly hyaline at the tip, with spots and bands of brown having darker borders. Hind border of tegmen creamy white without spots, continuing, when folded, the line of the median stripe of the head and pronotum. All main veins brown, except the hinder ones entering the white area of the hind border, where they become white also. In the pale areas the membrane is hyaline and the secondary longitudinal veins and all cross-veins are creamy white. The greater density of the creamy white colour towards the base of the tegmen is due to the very dense network of veins there, while the tip, having normal venation, is more hyaline. In the dark areas the membrane is brown, being darker near the veins, and the veins themselves are dark brown or black. In the apical halves of the fore and hind borders there is some mixing of brown and white veinlets. *Hind wings* hyaline, with the main veins dark and most of the subsidiary veins and veinlets pale brown or white.

Abdomen with the same pattern of markings as in the hopper, but with the ground-colour of segments 1-9 creamy white and the dark markings mauve-grey, the wavy, elongated oblique depressions in the lateral dark belt faintly brown and sometimes with a little brown suffusion on the hinder margins of the segments. Tip of abdomen orange, with an olive-brown suffusion. Females with the tip and

sharp edges of the ovipositor valves black. *Ventral surface* of thorax and abdomen very pale orange, suffused with faint olive-green cloudings except on the prosternum. Prosternal spine pale yellow.

Legs. Fore and middle coxae, trochanters and femora pale, with more or less pale olive-green suffusion and mauve-grey spotting below, and also with red suffusion on the hinder sides of the femora. Fore tibiae more heavily suffused with olive-green and mauve-grey, and with red on the hinder side. Middle tibiae red below, behind and above, and creamy white with mauve-grey spots in front. Hind femora creamy white, mostly more or less suffused with orange and red and with pale mauve-grey spots, especially in the position occupied in the hopper by the dark femoral band; raised line on upper and outer side especially dark, with red and grey or blackish spots; tip of hind femur with some black. Hind tibiae bright crimson pink. All tibial spines and spurs white with black tips. All tarsi with the upper sides mauve-grey with red suffusion. Claws black.

(b) *Later Swarm Colouring.*

Progressive changes in colouring, extending over several months, take place in the field. The following description is based on fresh material taken in late August.

Head-capsule. Face and lower and hinder corner of genae bright red or orange-red, with some blue-grey markings on the facial keels. Labrum and clypeus blue-grey, more or less marked and suffused with red. Base of mandibles dark reddish brown. Epicranium reddish brown to olive-brown, the pale median band almost or entirely obliterated, often bordered by two red lines converging towards the upper corners of the eyes. Remainder of genae reddish-brown to olive-brown, more or less marked with red lines or reticulations. Genal stripe olive-brown, borders of genal stripe bright red. Antennae red, the joints becoming darker from base to tip.

Pronotum bright red, the pale bands present in the young form being entirely obliterated. The dark lines bordering the position of the median band are generally visible, and the depressions in the lateral area are frequently pale brown. *Meso-* and *metanota* pale brown with darker markings. *Meso-* and *metapleurae* reddish brown to red, the proportion and distribution of the red and brown pigments varying greatly in different specimens.

Tegmina. General appearance bright red, fading to nearly hyaline at the tip. The spots and bands are brown with darker borders, as in the young form. The areas which were creamy white in the young form have become bright red owing to the reddening of the network of fine veins towards the base of the tegmen. The main veins entering this area are also red. *Hind wings.* Red pigmentation well developed in the basal third. Remainder hyaline.

Abdomen. Ground-colour light, somewhat reddish, brown, with a darker brown dorsal band on segments 1-9. Each segment often bears a rectangular mauve-coloured mark on either side of the median line and within the dorsal band. Sides obscurely marked, with paler and darker areas. Lower margins of tergites sometimes pale. Terminal segments somewhat darker brown than the ground-colour, hooks of the ovipositor valves of the female yellow with black tips. *Ventral surface of thorax and abdomen* brown, more or less extensively suffused and marbled with bluish or greenish grey.

Legs. Fore and mid coxae and trochanters reddish brown. Fore femur brownish red. Fore tibiae dark red, mid tibiae red with mauve and yellow markings in front. Fore and mid tarsi, reddish brown above, paler below. Hind coxae reddish brown. Hind femur with the central area between the raised margins yellowish grey with red lines, margins largely suffused with red, especially along the upper surface; a thin dark brown line extends along the upper raised margin. Swollen tip of femur dark brown above, pale reddish brown below. Hind tibia red, the outer surface between the spines darker red, spines pink with black tips. Hind tarsi dark reddish brown above, paler below.

(c) *Development of Swarm Colouring in the Field.*

The spreading of the bright red pigment over the head, pronotum, meso- and metapleurae, tegmina and legs, the development of the red colouring at the base of the hind wings, and the darkening of the ground-colour of the abdomen to brown or reddish brown occur gradually in the field. The pattern of dark and light coloration, so conspicuous in the young adult, is obscured and finally hidden.

The following notes are based on descriptions of fresh material taken from very large migrating swarms in 1933.

In specimens taken during May the pattern of light and dark coloration was generally clearly marked, but there was some development of bright red pigmentation on the epicranium, pronotum, meso- and metapleurae and legs, and very occasionally on the bases of the tegmina, typical specimens closely resembling Faure's figure (Pl. xvi, fig. 33). There was no development of the purplish red coloration at the base of the hind wings.

Material from several swarms was obtained during the earlier part of June and this showed further progression of the colour changes. The bright red pigmentation was well developed on the head, pronotum, meso- and metapleurae, legs and bases of tegmina, but rarely to such an extent as entirely to hide the pattern of light and dark areas, while the coloration of the bases of the hind wings was always developed to some extent.

No fresh material could be obtained in July.

The specimens taken during August probably show the completion of the colour change, since material taken late in the year during the previous season showed no further change until the development of a yellowish coloration associated with mating during November and December.

(d) *Mating Colours.*

The mating colours of *ph. gregaria* begin to develop at the commencement of the rains. In both sexes the bright red pigment of the head, pronotum, meso- and metapleurae, tegmina and legs, and the brown or reddish-brown pigments of the abdomen change more or less completely to yellowish brown, pure yellow, or greenish yellow. The change is generally most complete in the males and the following description refers to males taken *in coitu* during November.

Head-capsule. Face, clypeus, labrum, exposed mouth-parts, and lower and hinder corner of gena pale yellow, often with some vestige of reddish pigmentation on the face and gena. Epicranium dark olive-green with two broad, dark reddish, lines converging towards the upper corners of the eyes and forming a blunted V. Remainder of gena and genal stripe olive-green with a conspicuous pattern of pale reticulations. Border of genal stripe pale yellow to greenish yellow. Basal half or third of antennae yellow, remaining joints dusky, becoming darker towards the tip.

Pronotum. Lateral areas yellow to greenish yellow with small depressed pale brown marks. Dorsal aspect yellowish brown. *Meso- and metapleurae* yellow to greenish yellow.

Tegmina. Area of dense veinlets yellow, or yellowish brown. Hind border generally yellowish brown, resembling the colour of the dorsal aspect of the pronotum.

Abdomen. Ground-colour yellow to brownish yellow, the terminal segments generally more brownish. A conspicuous blue-grey mark with paler centre occurs on each side of the dorsal median line of segments 1-9. Lower margins of tergites white or cream-coloured. *Ventral surface of thorax and abdomen*, pale cream-colour to greenish yellow.

Legs. Fore and mid coxae and trochanters pale. Hind coxae and trochanters yellow to greenish yellow. Fore and mid femora yellow to greenish yellow with pale brown spottings on the outer surfaces. Hind femora yellow to greenish yellow

with a thin dark line along the upper raised margin and the swollen tip dark brown above and pale below. Tibiae yellow, the outer surface of the hind tibiae between the spines dark red. Spines white with black tips. Fore and mid tarsi pale brown, hind tarsi dark red above, paler below.

2. Colouring of *Ph. dissocians*.

(a) *Young Adults*.

Immediately after the ultimate moult adults of *ph. dissocians* are apparently indistinguishable in colour from those of *ph. gregaria*. After the hardening of the integument certain differences became distinguishable between young adults of *ph. gregaria* taken from the field (pp. 117-119) and material of *ph. dissocians* reared in the breeding cages. The following description applies to young adults from these cages.

Head-capsule. Face greyish brown, usually with darker cloudings on the keels. Clypeus, labrum and exposed mouth-parts pale olive-green. Epicranium with a pale whitish or greenish yellow median stripe. Remainder of epicranium and most of gena olive-grey. Genal stripe dark olive-green broadly bordered with very pale yellow. Eyes yellow with dark reddish brown bands, the bands being narrower than the spaces between.

Pronotum banded as in the young adult of *ph. gregaria*. The dark bands are dark brown to olive-grey in colour, sometimes infiltrated with red, but always less red than in the swarm type. Pale bands creamy white, the posterior two-fifths of the upper lateral band sometimes more or less suffused with reddish brown. *Meso- and metapleurae* pale olive-green to pale olive-brown, sometimes suffused with reddish brown. *Tegmina*. Colouring similar to that described for young adults of *ph. gregaria*. *Hind wings* hyaline.

Abdomen. Ground-colour of segments 1-9 creamy white and with the same pattern of markings as the *dissocians* hopper. The darker markings pale brown to grey.

Legs. Fore and middle legs with colouring similar to that described for young adults of *ph. gregaria* but suffused and coloured with crimson pink rather than red. Hind femora creamy white, mostly only slightly suffused with crimson pink along the upper margin; a black or dark brown line extends along the upper raised margin and a paler brown line along the lower margin. Hind tibiae purple (rose-colour to mallow-purple +), tibial spines white with black tips.

(b) *Colour Changes in Ph. transiens*.

In the case of the material of *ph. dissocians* kept in cages very slight colour changes took place. In large cages containing a few individuals a gradual darkening of the lighter areas occurred. After four months the border of the genal stripe was dull yellow to pink, the light bands of the pronotum dusky yellow and the ground-colour of the abdomen mauve brown to dusky yellow. In a few cases there was a slight suffusion of pink at the bases of the tegmina.

The coloration of the base of the hind wings differs from that of *ph. gregaria*, being bright purple rather than red, and develops considerably earlier than in *ph. gregaria*. The colouring began to appear in April and was well developed in most individuals by the end of May.

The colouring of *ph. transiens* individuals taken in the field (*congregans*? from the Kafue Flats) agreed with the description of cage material, the ratio of light to dark colouring remaining similar to that of the young adult throughout life, while the purple coloration of the hind wings was well developed in specimens taken during May.

(c) *Factors influencing Coloration.*

The adults obtained in cages in which hoppers had been reared under crowded conditions did not exhibit the changes in colouring observed in the field. This material failed to survive the low temperature and humidity of the winter months, but in July the last survivors showed no sign of change and were comparable in colouring with the *ph. dissocians* types.

Material taken from swarms in the field in early May and showing the development of red body pigmentation already described was placed in three cages of the same size.

The experiment was designed to investigate the effect of atmospheric humidity on breeding and the humidity within the cages varied. Cage 1 was of glass and in this a high humidity was maintained (diurnal range 70–100 per cent. R.H.). Cage 2 was of glass and in this the humidity was from 50–80 per cent. while Cage 3 was of wire netting and experienced the normal range of atmospheric humidity (20–60 per cent.).

In Cage 1 conditions were crowded for three months, some 400 adults being present. As a result of heavy mortality in the first few weeks Cages 2 and 3 were uncrowded, there being only some 40 or 50 adults in each.

After three months there was a marked colour change in the individuals in the crowded cage. The red colouring of the swarm type had become a dark brown and this colouring had spread over and obliterated the pale bands of the pronotum and had also spread to the area of dense veinlets on the tegmina, distribution of the brown pigment resembling that of the red body-colouring in later swarm types from the field. The red colouring of the hind wings was not developed except in a few individuals in which it showed as a very faint pinkish tinge.

Individuals from the uncrowded cages showed no change in body-colour after the same period of time, beyond the fading of the red pigment to brown, but the pigmentation of the hind wings was well developed and resembled the purple colouring of *ph. transiens*.

In order to find whether the variation in humidity had affected the colour change, individuals were taken from the uncrowded cages and isolated in small cages under high humidity conditions. In these specimens the red pigment of the swarm type had already changed to brown. This brown pigment gradually faded and after two months had entirely disappeared, revealing a pattern of very dark brown and yellow similar to that of the *ph. transiens* individual in which the red suffusion is lacking.

These observations appear to indicate the association of swarm colouring in the adult with crowding and possibly with activity. In all cages temperatures were sufficiently low to prohibit very active movement except for short periods, and this may account for the failure to obtain in cages the bright red colouring developed in the field.

The pigmentation of the hind wings in *ph. gregaria* and *ph. transiens* would appear to be of a different nature and their development would seem to be affected by different factors. In *ph. gregaria* the colouring may be of the same nature as that developed on other parts of the body, and its development may be influenced by the same factors.

3. Measurable Characters.

Biometrical data were obtained for a number of types. In all cases measurements were made by means of sliding callipers having a Vernier scale reading to 0.1 mm. Dried pinned material was used, the right tegmen and femur being removed and pinned on a flat surface. The characters studied were:—

A—Length of the tegmen from the notch between veins *Sc* and *R* to the tip.

B—Greatest width of the tegmen.

C—Length of the femur.

D—Length of the pronotum measured along the dorsal line.

E—Greatest width of the pronotum taken at the "shoulder."

F—Constriction of the pronotum measured by resting the ends of the callipers on the board to which the specimen was pinned and measuring the greatest width at the middle, since this was found less liable to error than a measurement taken at the deepest spot, to which, however, it bore a constant relation.

G—Width of the head at the widest point.

TABLE II.
Nomadacris septemfasciata : Mean Values of Measurable Characters.

Character measured	<i>Gregaria</i>							<i>Transiens</i>		
	Series	1	2	3	4	5	6	7	8	9
	No. of measurements $\left\{ \begin{array}{l} \text{♀} \\ \text{♂} \end{array} \right.$									
A	Females \pm	195 0.16	120 0.20	30 0.20	200 0.19	234 0.12	120 0.24	30	30	80 0.30
	Males \pm	195 0.12	120 0.18	30 0.18	150 0.16	234 0.10	100 0.21	30	30	70 0.30
B	Females \pm	56.2 0.03	54.8 0.04	56.5 0.04	57.5 0.03	57.6 0.03	56.3 0.05	50.4	56.7	59.0 0.05
	Males \pm	52.9 0.03	51.5 0.03	52.2 0.03	53.2 0.03	53.3 0.02	51.9 0.05	45.3	50.3	51.9 0.06
C	Females \pm	10.0 0.09	9.8 0.15	9.8 0.15	10.6 0.07	10.2 0.07	10.2 0.19	8.8	10.0	10.4 0.20
	Males \pm	9.7 0.07	9.5 0.11	9.5 0.11	10.2 0.07	9.8 0.05	9.7 0.19	8.1	8.9	9.5 0.21
D	Females \pm	26.6 0.07	26.4 0.11	27.7 0.11	27.4 0.07	27.7 0.05	27.3 0.19		30.2	31.9 0.21
	Males \pm	25.1 0.07	24.8 0.11	25.2 0.11	25.3 0.07	25.8 0.05	25.1 0.19		26.3	27.5 0.21
E	Females \pm	10.2 0.03	9.9 0.04	10.4 0.04	10.5 0.03	10.6 0.03	10.3 0.08	9.3	10.7	11.5 0.07
	Males \pm	9.7 0.03	9.5 0.04	9.6 0.04	10.0 0.03	9.9 0.02	9.7 0.07	8.5	9.9	10.1 0.06
F	Females \pm	8.9 0.03	9.3 0.05	8.6 0.05	9.2 0.02	9.0 0.02	8.9 0.04	7.7	8.7	9.5 0.05
	Males \pm	8.4 0.02	8.6 0.04	8.0 0.04	8.4 0.03	8.3 0.01	8.4 0.06	6.8	7.7	8.3 0.06
G	Females \pm	7.2 0.02	7.2 0.04	7.2 0.04	7.2 0.04	7.3 0.02	7.3 0.04	6.5	7.5	8.3 0.04
	Males \pm	6.6 0.02	6.8 0.03	6.6 0.03	6.8 0.03	6.6 0.01	6.8 0.05	5.8	6.5	7.4 0.04
H	Females \pm	8.1 0.02	8.1 0.05	8.0 0.05	8.2 0.02	8.2 0.02	8.1 0.03	7.3	8.2	8.3 0.04
	Males \pm	7.6 0.02	7.5 0.02	7.3 0.02	7.7 0.02	7.6 0.01	7.5 0.04	6.7	7.2	7.4 0.04

Table II shows the mean values of these measurements together with an estimate of the standard error of the mean, where the number of observations was sufficient to permit of its calculation.

The ratios A/B, A/C, A/D, D/E, E/F, and G/F, were calculated independently for each specimen measured in order to allow of the calculation of the standard errors of the means of the ratios, with the object of determining what differences in the means could be regarded with confidence.

Table III shows the mean values of these ratios and the standard errors are appended to the appropriate quantities.

TABLE III.
Nomadacris septemfasciata : Mean Values of Ratios.

Ratio	<i>Gregaria</i>							<i>Transiens</i>		
	Series	1	2	3	4	5	6	7	8	9
	No. of observations $\left\{ \begin{array}{l} \text{♀} \\ \text{♂} \end{array} \right.$	195	120	30	200	234	120	30	30	80
$\frac{A}{B}$	Females \pm	5.62 0.01	5.59 0.02	5.76	5.42 0.01	5.62 0.01	5.52 0.01	5.73	5.67	5.67 0.02
	Males \pm	5.45 0.01	5.42 0.03	5.53	5.22 0.01	5.47 0.009	5.35 0.01	5.59	5.51	5.46 0.02
$\frac{A}{C}$	Females \pm	2.11 0.004	2.08 0.006	2.05	2.10 0.003	2.08 0.003	2.06 0.007		1.88	1.85 0.008
	Males \pm	2.11 0.004	2.08 0.006	2.07	2.10 0.004	2.07 0.003	2.07 0.008		1.89	1.89 0.008
$\frac{A}{D}$	Females \pm	5.54 0.01	5.53 0.02	5.43	5.48 0.01	5.46 0.01	5.47 0.02	5.44	5.30	5.13 0.03
	Males \pm	5.45 0.01	5.42 0.04	5.43	5.32 0.01	5.38 0.01	5.40 0.02	5.29	5.08	5.14 0.04
$\frac{D}{E}$	Females \pm	1.14 0.002	1.09 0.004	1.21	1.14 0.003	1.17 0.003	1.16 0.004	1.20	1.23	1.21 0.005
	Males \pm	1.15 0.003	1.10 0.004	1.20	1.19 0.005	1.19 0.003	1.15 0.005	1.25	1.26	1.22 0.005
$\frac{E}{F}$	Females \pm	1.24 0.004	1.29 0.004	1.20	1.28 0.003	1.23 0.003	1.22 0.004	1.17	1.16	1.15 0.004
	Males \pm	1.26 0.004	1.26 0.004	1.22	1.23 0.003	1.26 1.003	1.23 0.004	1.17	1.18	1.12 0.005
$\frac{G}{F}$	Females \pm	1.12 0.003	1.12 0.004	1.11	1.14 0.002	1.12 0.002	1.11 0.003	1.12	1.09	1.00 0.004
	Males \pm	1.15 0.002	1.10 0.004	1.12	1.13 0.004	1.15 0.002	1.10 0.003	1.16	1.11	1.00 0.004

Description of Material.

The material from which the data were derived is described below. In indicating the colour characteristics of the types it will be convenient to distinguish between early swarm-colouring in the case of specimens showing some development of the red body pigment but with the pattern of light and dark areas of the young adult still distinguishable, late swarm-colouring in which the red pigment is fully developed, and "*transiens*" colouring similar to that described (p. 121).

Series (1) consisted of material taken from a very large, dense swarm at Mazabuka in June 1933. The swarm was estimated at some fifteen miles in length and some five miles in width. All individuals showed early swarm-colouring.

Series (2) were taken at Abercorn in November 1932, from a very large, dense swarm of the same order. Colouring was of the late swarm type.

Series (3) were collected at Kalomo from a swarm which invaded North Western Rhodesia in December 1930 from the Belgian Congo. The size was not estimated but was undoubtedly small compared with (1) and (2). Colouring was of the late swarm type.

Series (4) consisted of a collection of young adults taken at Lusaka in April 1933 and derived from hoppers the behaviour and colouring of which have been described (p. 115). These took to flight in small but dense swarms. Their subsequent behaviour is unknown.

Series (5) were collected from a very small loose swarm on the Kafue Flats in August 1933. Colouring was of the early swarm type with a very slight development of the red body pigmentation, although in material taken from large swarms during the month the red pigment was fully developed. Small swarms of this type were fairly numerous on the flats and were believed to consist mainly of aggregates of individuals left behind by the repeated passage of swarms.

Series (6) were taken from a very small and loose swarm at Mazabuka in December 1932. The colouring was not quite of the late swarm type, the light areas in the colour pattern being distinguishable although suffused with red.

Series (7) consisted of a collection from a small, loose swarm on Mweru Marsh in November 1930. The colouring was typical *transiens* with no development of red body pigmentation, the individuals being probably of ph. *congregans*.

Series (8) consisted of young adults collected in Machili Valley in March 1931, and undoubtedly the progeny of the swarm from which series (4) was derived. They occurred in very loose aggregates of individuals and from their history and hopper coloration could be referred to ph. *dissocians*.

Series (9) were collected from the Kafue Flats in 1931, before swarms were known to have appeared in the vicinity. They consisted of more or less isolated individuals with a definite tendency to congregate and might be described as "*solitaria* beginning to congregate." The colouring was of the *transiens* type irrespective of the time of year at which they were collected.

Discussion of Biometrical Data.

It will be seen from inspection of Table II that in all cases the mean value of any measurement for females greatly exceeds the corresponding value for the males and that the difference is greater in the case of the *transiens* series.

The relative size of the sexes is shown below by expressing the wing length of the male as a percentage of that of the female.

TABLE IV.
Wing Length of Males as Percentage of that of Female.

Series	<i>Gregaria</i>						<i>Transiens</i>		
	1	2	3	4	5	6	7	8	9
%	94.1	94.0	94.2	92.5	92.5	92.2	89.9	88.7	88.0

The data in Table III show clearly certain differences in the relative size of femur and wing, and in the structure of the pronotum, serving to distinguish the *transiens* and *gregaria* types.

In the case of the ratio A/C there is no significant difference in the means calculated for females and males. The ratios for series (1) and (4) would appear to show some aberration from the other means for *gregaria*, but the ratio for specimens from small swarms shows no significant difference from that calculated for individuals from the very large dense swarm at Abercorn. On the other hand the femur is considerably longer in relation to the wing in *transiens* types, the difference between the ratio for "*solitaria* beginning to congregate" and *gregaria* being manifestly significant.

The ratio A/B shows the width of the wing in relation to its length. The variation in this ratio is apparently not associated with phase, but in all cases there is a marked difference in its value for males and females in each series, the wing being relatively wider in the case of the males.

The ratio A/D represents the extreme length of the pronotum in relation to that of the wing. In the case both of males and females of "*solitaria* beginning to congregate" the pronotum is relatively very long compared with other types. In *dissocians* the pronotum is long in the males and shorter in the females, while in the case of *congregans* from Mweru Marsh the pronotum of the females is shortened to the same extent as in typical *gregaria*. In types of *gregaria* from very large and dense swarms the pronotum is relatively shorter than in other types, except in the case of the males of series (3). In this series the pronotum of the male is apparently shortened to the same extent as in types from large swarms, while that of the female is relatively longer. In all samples of *gregaria* except series (3) and apparently in *congregans* from Mweru Marsh and *dissocians* the pronotum of the male is relatively longer than that of the female, while in "*solitaria* beginning to congregate" there is no difference in the relative lengths. It would appear that in *gregaria* the pronotal length tends to approximate to the width of the wing.

The ratio D/E expresses the extreme width of the pronotum in relation to its length. In "*solitaria* beginning to congregate" and in *congregans* from Mweru Marsh and *transiens* types the relative width is less than in *gregaria*. An exception occurs in the case of series (3), for which the ratio appears to approximate to the *transiens* order.

The ratio E/F expresses the degree of constriction of the pronotum. The figures show clearly that in *gregaria* the pronotum is markedly more constricted than in any of the *transiens* forms. Series (3) again shows some aberration from the other means for *gregaria*, the pronotum being somewhat less constricted.

The ratio G/F, which measures the constriction of the pronotum in relation to the width of the head, does not appear to give a reliable measure of difference between the phases. In "*solitaria* beginning to congregate" the ratio is unity, while in the other series the width of the head exceeds that of the pronotum at its narrowest part.

Summary.

1. The egg, vermiform larva, and the nymphal stages of ph. *gregaria* are described. It is shown that six stages occur, or seven instars including the vermiform larva. These stages can be distinguished by (a) the number of antennal joints, (b) the degree of backward prolongation of the pronotum, (c) the differentiation of the terminal abdominal structures. Measurements of the pronotum and femur served to distinguish the stages in material from the same swarm, but the absolute measurements cannot be used to distinguish material from different sources.

2. The colour pattern of ph. *dissocians* is analysed, and colour changes are indicated as divergences from the *gregaria* pattern. Forms of ph. *dissocians* observed in the field are grouped into several types the relationships of which are illustrated, and the environmental factors which produce them are discussed.

3. Hoppers believed to be of ph. *congregans* could not be distinguished from certain forms of ph. *dissocians*.

4. Cage experiments in which hoppers were reared under varying degrees of crowding are described. It is strongly indicated that activity which is induced by crowding influences the development of *gregaria* colouring. The green colouring of *dissocians* hoppers appears to be associated with high humidity conditions and the presence of green food. Other colours of *dissocians* hoppers are conditioned by those of the environment.

5. An aberrant pallid type of hopper is described and its origin is ascribed to the effects of parasitism by Nematodes and possibly also by Dipterous larvae.

6. Certain inferences regarding the processes in the formation of the colour pattern are inferred from a consideration of the effects of parasitism and of *dissocians* producing factors.

7. The colourings of young adults of ph. *gregaria* a few days after the ultimate moult and of types taken from large swarms in August are described. It is shown that colour changes occur gradually in the field, the conspicuous pattern of light and dark coloration of the young adult being obscured and finally hidden by the development of a bright red pigmentation.

8. The colouring of young adults of ph. *dissocians* is described. These show a pattern of light and dark coloration similar to that of the young adult of ph. *gregaria*, from which it is indistinguishable, immediately after the ultimate moult. In ph. *transiens* no marked colour change takes place throughout the life of the individual except the development of a purple coloration on the hind wings.

9. Factors influencing adult colouring are discussed. Adults crowded in cages and derived from hoppers reared under crowded conditions did not undergo the colour changes observed in the field. Material taken from large swarms in the field and showing some development of swarm colouring were maintained under crowded and uncrowded conditions. The red pigment of the body changed to a dark brown in both cases. Under uncrowded conditions no further change took place except a conspicuous development of purple coloration on the hind wings in all individuals. Under crowded conditions the brown pigment spread, its final distribution resembling that of the red pigment in later swarm types from the field, but the red colouring of the hind wings was developed only to a very slight extent in a few individuals. In the case of individuals isolated completely the swarm colouring was lost entirely.

10. It is inferred that swarm colouring in the adult is associated with crowding and possibly with activity and that development of the red and purple coloration on the hind wings in *gregaria* and *transiens* is affected by different factors and possibly differs in composition.

11. Biometrical data obtained from a variety of types is tabulated and discussed. Material varied from types taken from very large and dense swarms to what might be described as "*solitaria* beginning to congregate."

12. It is shown that certain measurable characters, especially the relative size of the sexes, the degree of development of the femur in relation to the wing, and the relative length and degree of constriction of the pronotum differ greatly in *gregaria* and *transiens* types and may be used to distinguish them.

13. In the case of material from very large and dense swarms and from very small loose swarms no differences in the characters on which the types could readily be distinguished were observed. It may be that these small groups were derived from larger swarms.

14. Interesting aberrations occur in the case of a swarm believed to have been one of the earliest to migrate any considerable distance after the commencement of swarming. The quantity of material was insufficient to permit of very reliable

comparison but it would appear that in these forms the pronotum of the female was generally not shortened or constricted to the same extent as in extreme *gregaria*, although the construction of the pronotum of the male approximated fairly closely to that of more extreme *gregaria*.

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LIST OF CHALCID FLIES (HYM.) REARED IN U.S.S.R.

By M. NIKOL'SKAYA.

This paper records a number of parasitic and phytophagous species of CHALCIDIDAE that have been reared in U.S.S.R. during recent years. The material was partly collected by the author herself, or received for identification from various persons and institutions.

Ashmead's systematic order has been taken as the basis, but changes have been made in accordance with Dr. Handlirsch's last arrangement of the subfamilies. With regard to the subfamilies PTEROMALINAE and MISCOGASTERINAE the author agrees with N. V. Kurdjumov's classification.

Three new species of EURYTOMINAE are described in addition to the list and marked with an asterisk in the text.

FAMILY CHALCIDIDAE.

SUBFAM. AGAONINAE.

Blastophaga psenes, L.—In immature fruit of *Ficus carica*, L. Sukhum, ix.1932.

SUBFAM. TORYMINAE.

Philotrypesis carica, L.—In immature fruit of *Ficus carica*, L. Sukhum, ix.1932.

Diomorus kollari, Dalm.—Ex *Salvia sclarea* stems; probably on some wasp. Crimea, vii.1929.

Syntomaspis druparum, Boh.—In seeds of *Pirus malus*, L. Moscow, v–vii.1927.

Torymus bedeguaris, L.—Ex *Rhodites rosae*, L., galls on *Rosa cinnamomea*, L. Poltava, 1916.

Torymus macropterus, Walk.—Ex Cynipid galls on *Rubus idaeus*, L. Poltava, 1916.

Torymus quercinus, Boh.—From heads of *Carthamus tinctorius*, L., containing *Acanthiophilus helianthi*, Schr. Saratov, 1925; Crimea, viii.1931.

Torymus azureus, Boh.—From fir-cones. Ohansk, Kama R., 1931.

Liodontomerus perplexus, Gah.—Ex *Bruchophagus gibbus*, Boh., in seeds of *Medicago sativa*, L.; ex *Eurytoma onobrychidis*, sp. n., in seeds of *Onobrychis sativa*, Lam. Poltava, vii.1927–28.

Liodontomerus secundus, Gah.—Ex *Bruchophagus gibbus*, Boh., in seeds of *Trifolium pratense*, L. Poltava, ix.1927.

Monodontomerus aereus, Walk.—Ex *Aporia crataegi*, L., pupae. Poltava, vi.1927.

Monodontomerus dentipes, Boh.—Ex *Aporia crataegi*, L., pupae. N.-Novgorod, vii.1925.

Oligosthenus stigma, Fabr.—Ex *Rhodites rosae*, L., galls on *Rosa cinnamomea*, L. Poltava, vi.1929.

Pseudotorymus militaris, Boh.—From *Papaver somniferum*, L., and *Camelina sativa*, L., probably on Cecidomyiidae in the fruit. Poltava, viii.1928–29.

Pseudotorymus pannonicus, Mayr.—*Camelina sativa*, L., seed-pods with larvae of Cecidomyiidae. Poltava, vii–viii.1928–29.

Megastigmus aculeatus, Swed.—From seeds of *Rosa cinnamomea*, L. Poltava, 1916 ; N. Caucasus, Kuban, vi.1931.

Megastigmus pistaciae, Walk.—From fruit of *Pistacia mutica* and *Pistacia vera*, L. Crimea, viii.1930 ; Apsheron, 1932 ; Turcomania, Kushka, 1930.

Megastigmus strobilobius, Ratz.—From seeds of *Abies* sp. Moscow, 1928.

SUBFAM. ORMYRINAE.

Ormyrus punctiger, Westw.—From heads of *Carthamus tinctorius*, L., containing *Acanthiophilus helianthi*, Schr. Saratov, viii.1921.

*Ormyrus wachtl*i, Mayr—From seeds of *Salvia grandiflora*. Crimea, viii.1931.

SUBFAM. CHALCIDINAE.

Chalcis femorata, Panz.—*Aporia crataegi*, L., pupae ; *Pieris daplidicac*, L., pupae. Poltava, vi.1924 ; Stalingrad, vii.1926.

Chalcis fonscolombi, Duf. Tachinid puparia from *Schistocerca gregaria*, Forsk., Bairam-Ali, vii.1929 ; Tachinid puparia from Acrididae, Tomsk, xii.1931.

Chalcis intermedia, Nees—*Aporia crataegi*, L., pupae, Poltava, vi.1924 ; *Acalla variegana*, Sch., Crimea, vii.1930 ; *Pieris rapae*, L., pupae, Rostov on Don, viii.1929 ; *Sparganothis pilleriana*, Sch., on tea-plants, Batum, 1930.

Chalcis minuta, L.—Tachinid puparia, Stavropol, 1913 ; Tachinid puparia from nests of *Hyponomeuta malinellus*, Z., Poltava, vii.1928.

Chalcis rugulosa, Foerst.—Ichneumonid cocoons from *Heliothis peltigera*, Sch., Crimea, vii.1930 ; *Depressaria depressella*, Hb., pupae, Don reg., Kajala, viii.1930.

Chalcis vitripennis, Foerst—*Cassida nebulosa*, L., pupae, Poltava, vi.1929, vii.1931 ; Rostov on Don, viii.1929.

Hockeria bispinosa, Walk.—*Pieris rapae*, L., pupae, Rostov on Don, viii.1929 ; *Polychrosis botrana*, Sch., Crimea, vii.1930.

SUBFAM. EURYTOMINAE.

Isosoma phyllostachitis, Gah.—*Bambusa* sp., young stems, Batum, viii.1930.

Bruchophagus gibbus, Boh.—*Trifolium pratense*, L., seeds, N.-Novgorod, vii.1925, Vjatka, iv.1932 ; Ukraine, Belaja Tserkov, vii.1928 ; *Medicago sativa*, L., seeds, Ramon, 1930 ; Poltava, 1927–28 ; N.-Novgorod, vii–viii.1932 ; Kamennaja Steppe, iv.1932.

Eurytoma amygdali, End.—In fruit of *Prunus domestica*, L. Poltava, v.1929, 1931.

Eurytoma appendigaster, Dalm.—*Apanteles glomeratus*, L., cocoons, N.-Novgorod, vi.1925 ; *Apanteles fulvipes*, Hald., cocoons, Poltava, vii.1928.

Eurytoma dentata, Mayr—*Medicago sativa*, L., galls of *Asphondylia miki*, Wachtl, Poltava, viii.1931.

Eurytoma infracta, Mayr—*Salvia grandiflora*, seeds, Crimea, viii.1931.

* *Eurytoma onobrychidis*, sp. n.—*Onobrychis sativa*, Lam., seeds, Poltava, 1927.

* *Eurytoma plotnikovi*, sp. n.—*Pistacia vera*, L., fruit, Turcomania, Kushka, 1930.

Eurytoma rosae, Nees—*Rhodites rosae*, L., galls on *Rosa cinnamomea*, L., Poltava, v.1929.

Eurytoma setigera, Mayr—*Megastigmus pistaciae*, Walk., in *Pistacia vera*, L., Turcomania, Kushka, 1930 ; in *Pistacia mutica* Crimea, 1930.

- Eurytoma strigifrons*, Thom.—*Apanteles glomeratus*, L., cocoons, Poltava.
 * *Systole coriandri*, sp. n.—*Coriandrum sativum*, L., seeds, Don reg., Kajala, vii.1930; Kamennaja Step, vii.1932.
Decatoma biguttata, Swed.—*Megastigmus pistaciae*, Walk., in *Pistacia mutica*, Crimea, ix.1930; *Biorrhiza pallida*, Ol., galls on *Quercus* sp., Poltava, vi.1927.
Decatoma mellea, Walk.—*Agropyrum repens*, L., probably on *Harmolita* sp., Kiev, viii.1932.

SUBFAM. PERILAMPINAE.

- Perilampus auratus*, Panz.—Tachinid puparia from *Pyrausta nubilalis*, Hb., N.-Novgorod, 1931.
Perilampus italicus, Fabr.—*Athalia colibri*, Christ, cocoons, Moscow, v.1925, 1926; Poltava, viii.1929.
Perilampus nitens, Walk.—*Larvaevora noctuarum*, Rond., puparia from *Loxostege sticticalis*, L., Koslovsky sect., Central Chernozem region, 1931; Barnaul, 1930.
Perilampus violaceus, Fabr.—Tachinid puparia, Crimea, 1931.

SUBFAM. ENCYRTINAE.

- Ageniaspis fuscicollis*, Dalm.—*Hyponomeuta malinellus*, Z., N.-Novgorod, 1923; larvae on *Pinus malus*, L., Poltava, vi-vii.1927, 1929; Baku, 1930; Rostov on Don, vi.1930. *Hyponomeuta euonymellus*, L., larvae on *Prunus padus*, L., Moscow, vii.1928; Tomsk, vii.1926. *Hyponomeuta padellus*, L., larvae on *Prunus spinosa*, L., Poltava, vii.1927.
Anagyrus bohemani, Westw.—*Phaenacoccus aceris*, Sign., Mleevo, vi.1928.
Aphidencyrtus aphidivorus, Mayr—*Brevicoryne brassicae*, L., N.-Novgorod, viii.1925; Moscow, ix.1925.
Blastothrix sericeus, Dalm.—*Lecanium persicae*, Fabr., Crimea, 1931.
Cerapterocerus mirabilis, Westw.—*Physokermes coryli*, L., Mleevo, viii.1927; *Lecanium prunastri*, Sulc, Caucasus, Badara, v.1932.
Chiloneurinus microphagus, Mayr—*Aspidiotus ostreaeformis*, Curt., on *Prunus spinosa*, L., N. Caucasus, Maikop, vi.1932.
Chiloneurus formosus, Boh.—Syrphid puparia, Crimea, vii.1931; *Lecanium persicae*, Fabr., Crimea, vii.1931.
Encyrtus ferrugineus, Nees—*Physokermes coryli*, L., *Pulvinaria betulae*, L., Mleevo, 1928, 1929.
Habrolepis zetterstedti, Westw.—*Aspidiotus ostreaeformis*, Curt., on *Prunus spinosa*, L., N. Caucasus, Maikop, vi.1932.
Encyrtus tessellatus, Dalm.—*Lecanium* sp., Mleevo, vii.1929.
Homalotylus flaminus, Dalm.—*Coccinella septempunctata*, L., larvae, N.-Novgorod, viii.1925.
Litomastix truncatellus, Dalm.—*Phytometra gamma*, L., larvae, N.-Novgorod, viii.1932; Moscow, viii.1927; Ukraine, Lubnui, vi. 1931; Ramon, 1930.
Microterys aeruginosus, Dalm.—Syrphid puparia, N.-Novgorod, viii.1925.
Phaenodiscus aeneus, Dalm.—*Lecanium persicae* Fabr., Crimea, 1931; *L. prunastri*, Sulc, Caucasus, v.1932; *Physokermes coryli*, L., *Pulvinaria betulae*, L., Mleevo, viii.1927-28.
Psilophrys longicornis, Walk.—*Kermes*, N. Caucasus, Maikop, vi.1932.

SUBFAM. EUPELMINAE.

- Anastatus bifasciatus*, Fonsc., v. *disparis*, Rusch.—*Porthetria dispar*, L., eggs, Crimea, ix.1932.
- Eupelmus atropurpureus*, Dalm.—*Mayetiola destructor*, Say, puparia, Poltava, viii.1925; Kharkov, vii.1931; *Cephus pygmaeus*, L., cocoons in wheat stems, Poltava, 1928–29; *Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, 1927; *Chlorops pumilionis*, Bjerk., puparia, *Meromyza saltatrix*, L., puparia, *Lasiosina cinctipes*, Meig., puparia, Poltava, 1927.
- Eupelmus fulvipes*, Foerst.—*Megastigmus pistaciae*, Walk., in *Pistacia mutica* fruit, Crimea, ix.1930.
- Eupelmus linearis* Foerst.—*Phleum pratense*, L., probably on *Isosoma* sp., Kiev, viii.1932.
- Eupelmus microzonus*, Foerst.—*Bruchus rufimanus*, Boh., Poltava, viii.1920; *Mayetiola destructor*, Say, puparia, Poltava, viii.1925; *Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, vii.1928; *Tychius (medicaginis?)* larvae on *Medicago sativa*, L., Saratov, viii.1931; *Chlorops pumilionis*, Bjerk., puparia, *Meromyza saltatrix*, L., puparia, *Lasiosina cinctipes*, Meig., puparia, Poltava, 1927.
- Eupelmus spongipartus*, Foerst.—*Biorrhiza pallida*, Ol., galls on *Quercus* sp., Poltava, vii.1926.
- Eupelmus urozonus*, Dalm.—*Anthribus nebulosus*, Foerst., in *Lecanium corni*, Bouché, Mleeevo, vii.1928.
- Eupelmus vesicularis*, Ratz.—*Mayetiola destructor*, Say, puparia, Poltava, 1924; *Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, vii.1927; *Chlorops pumilionis*, Bjerk., puparia, *Meromyza saltatrix*, L., puparia, Poltava, 1927.

SUBFAM. PTEROMALINAE.

- Arthrolysis scabriculus*, Nees—*Cephus pygmaeus*, L., cocoons in wheat stems, Poltava, 1927–28.
- Dinarmus robustus*, Masi—*Megastigmus pistaciae*, Walk., on *Pistacia mutica*, Crimea, viii.1930; on *P. vera*, Turcomania, Kushka, 1930.
- Bruchobius laticeps*, Ash.—*Bruchus rufimanus*, Boh., Poltava, viii.1920.
- Catolaccus ater*, Ratz.—*Apanteles glomeratus*, L., cocoons, Poltava, 1927; *Phytometra (Plusia) gamma*, L., cocoons, N.-Novgorod, viii.1931.
- Catolaccus cavigena*, Thom.—*Anilastus* sp., cocoons, Azerbaidjan, v.1927.
- Dibrachys boucheanus*, Ratz.—*Aporia crataegi*, L., pupae, *Apanteles glomeratus*, L., cocoons, N.-Novgorod, vi–vii.1925; Ichneumonid cocoons from *Pyrausta nubilalis*, Hb., N.-Novgorod, iv.1930; *Apanteles fulvipes*, Hald., cocoons, Poltava, vii.1928; *Anilastus ebeninus*, Grav., cocoons, Rostov on Don, viii.1930; *Ageniaspis fuscicollis*, Dalm., cocoons in larvae of *Hyponomeuta malinellus*, Z., N.-Novgorod, 1922, Poltava, vii.1928, Rostov on Don, vi.1930; Ichneumonid cocoons from *H. malinellus*, Z., Poltava, vii.1928, Alma Ata, vii.1930; Tachinid puparia from *Curpocapsa pomonella*, L., Crimea, viii.1928; *Cerostoma persicella*, Sch., Crimea, vi.1930; *Canidia curculionis*, Thom., cocoons, Ukraine, Belaja Zerkov, ix.1932; *Euproctis chrysorrhoea*, L., cocoons, *Chrysopa* sp., cocoons, Crimea, ix.1932.
- Eupteromalus arvensis*, Kurd.—*Mayetiola destructor*, Say, puparia, Poltava, vi–viii.1924–29, Kharkov, vii.1931, Odessa, 1930; *Oscinosoma frit*, L., puparia, N.-Novgorod, 1924.
- Eupteromalus nidulans*, Thom.—*Euproctis chrysorrhoea*, L., from nests, Voronesh, 1927.

- Habrocytus bedeguaris*, Thom.—*Rhodites rosae*, L., galls on *Rosa cinnamomea*, L., Poltava, v.1929.
- Habrocytus medicaginis*, Gah.—*Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp.n., Poltava, vii.1927–28, Kamennaja Steppe, viii.1930–32.
- Habrocytus microgasteris* (Bché.) Kurd.—*Apanteles glomeratus*, L., cocoons, N.-Novgorod, vii.1925, Voronezh, vi.1927, Leningrad, viii.1931, Ukraine, Lubnui, 1931; Ichneumonid puparia from *Hyponomeuta malinellus*, Z., Poltava, vii.1928; 29; *Tychius medicaginis*, Bris., galls on *Medicago sativa*, L., Poltava, viii.1931, Saratov, viii.1931.
- Habrocytus tenuicornis*, Foerst.—*Anthonomus pomorum*, L., larvae and pupae, N.-Novgorod, vi.1925–31, Poltava, vi.1927.
- Homoporus luniger*, Nees—*Agropyrum repens*, P. B., probably on *Isosoma* sp., Kiev, viii.1932.
- Lariophagus distinguendus*, Foerst.—*Stegobium (Sitodrepa) paniceum*, L., Baku, 1929, Crimea, xii–i.1930, N.-Novgorod, iv.1931, Moscow, vi.1932, Leningrad, xi.1931; *Calandra granaria*, L., Leningrad, xi.1931.
- Meraporus crassicornis*, Kurd.—*Mayetiola destructor*, Say, puparia, Poltava, v.1926, Odessa, 1930.
- Merisus destructor*, Say (= *intermedius*, Lind.)—*Mayetiola destructor*, Say, puparia, Poltava, 1925, Odessa, 1930, Kharkov, vii.1931.
- Micromelus rufomaculatus*, Walk. (*Callitula bicolor*, Spin.)—*Mayetiola destructor*, Say, puparia, Poltava, 1925, Odessa, 1930, Kharkov, vii.1931; *Oscinosoma frit*, L., puparia, Moscow, 1927, N.-Novgorod, 1924, Ufa, vi.1930; *Chlorops pumilionis*, Bjerk., puparia, Poltava, 1927, Leningrad, 1927; *Meromyza saltatrix*, L., puparia, *Lasiosina cinctipes*, Meig., puparia, Poltava, 1927.
- Mormoniella (Nasonia) brevicornis*, Ash.—*Calliphora erythrocephala*, Meig., puparia, Moscow, vii.1931.
- Pseudocatolaccus asphondyliae*, Masi—*Asphondylia miki*, Wachtl, galls on *Medicago sativa*, L., Ukraine, Belaja Zerkov, vii.1930.
- Pteromalus puparum*, Swed.—*Papilio machaon*, L., pupae, Kara-Kum, 1931; *Pieris brassicae*, L., pupae, *Pieris rapae*, L., pupae, N.-Novgorod, iii.1931, Moscow, ix.1925, Rostov on Don, viii.1925, Leningrad, ix.1930; *Pyrameis cardui*, L., pupae, N.-Novgorod, 1925; *Vanessa io*, L., pupae, Poltava, vii.1927; *Vanessa urticae*, L., pupae, Irkutsk, xi.1931, Poltava, vi.1927; *Vanessa xanthomelas*, Esp., pupae, Moscow, vii.1926.
- Raphitelus ladenbergi*, Ratz.—*Hylesinus oleiperda*, F., Crimea, viii.1929.
- Rhopalicus suspensus*, Ratz.—Scolytidae from *Picea vulgaris*, Link., Minsk, viii.1929.
- Roptrocercus xylophagorum*, Ratz.—Scolytidae from *Picea vulgaris*, Minsk, vii.1929, Orsha, vii.1930.
- Spintherus linearis*, Walk.—*Apion* spp. from *Trifolium pratense*, L., N.-Novgorod, vii.1925, Moscow, xi.1925, Ukraine, Belaja Tserkov, viii.1928.
- Stenomalus laetus*, Rush.—*Chlorops pumilionis*, Bjerk., puparia, N.-Novgorod, 1924, Moscow, vi.1927, Poltava, 1927–29.
- Stenomalus micans*, Ol.—*Chlorops pumilionis*, Bjerk., puparia, Poltava, 1927–29, N.-Novgorod, 1924, Moscow, 1924–25; *Meromyza saltatrix*, L., puparia, Poltava, 1927.
- Stenomalus muscarum*, Thom.—Tachinid puparia from *Pyrausta nubilalis*, Hb., Shatilovskaja Exp. Sta., 1930.
- Trichomalus cristatus*, Foerst.—*Oscinosoma frit*, L., puparia, N.-Novgorod, 1924, Moscow, 1925–27, Ivanovo-Voznesensk, 1926, Ufa, vi–viii.1928–30, Vjatka, vii.1931.

SUBFAM. MISCOGASTERINAE.

- Halticoptera petiolata*, Thom.—*Oscinosoma frit*, L., puparia, N.-Novgorod, 1924, Moscow, 1925–27, Ufa, vi.1930, Odessa, 1930.
- Asaphes vulgaris*, Walk.—*Brevicoryne brassicae*, L., Moscow, ix.1925–27, N.-Novgorod viii.1925 ; *Capitophorus ribis*, L., N.-Novgorod, vii.1925 ; *Aphelinus mali*, Hald., in *Eriosoma lanigerum*, Hausm., Crimea, vii.1931.
- Pachyneuron aphidis*, Bché.—*Brevicoryne brassicae*, L., Moscow, ix.1925 ; *Aphelinus mali* in *E. lanigerum*, Crimea, v-ix.1931–32, Azerbaidjan, viii-ix.1932.
- Pachyneuron syrphi*, Ash.—Syrphid puparia, Moscow, vii.1923, N.-Novgorod, iii.1926, Poltava, viii.1929 ; *Coccinella septempunctata*, L., larvae, N.-Novgorod, iii.1926.
- Sphegigaster aeneicornis*, Ratz.—Puparia from galls on *Mentha piperita*, probably of *Asphondylia menthae*, Kieff., Maikop, ix.1931.

SUBFAM. TRIDYMINAE.

- Scutellista aenea*, Kurd.—*Eriococcus* sp. on Gramineae, Kalmyk region, 1932.

SUBFAM. ELASMINAE.

- Elasmus flabellatus*, Westw.—*Hyponomeuta malinellus*, Z., cocoons, *H. padellus*, L., cocoons, Poltava, vii.1927–28 ; *Prays oleaellus*, Fabr., Crimea, vii.1929.

SUBFAM. EULOPHINAE.

- Euplectrus bicolor*, Swed.—*Barathra brassicae*, L., larvae, Ufa, ix.1928 ; *Phytometra gamma*, L., larvae, Ramon, 1930 ; *Cirphis unipunctata*, Hw., larvae, Vladivostok, 1930.
- Cratotechus longicornis*, Thom.—*Pygaera anachoreta*, F., larvae, N.-Novgorod, vii.1931 ; Tortricid larvae, Mleevo, vi.1929 ; Noctuid larvae, Moscow, viii.1931.
- Eulophus longulus*, Zett.—*Lithocolletis populifoliella*, Tr., N.-Novgorod, vii.1925.
- Eulophus pectinicornis*, L.—Noctuid larvae on cabbage, Leningrad, 1932.
- Eulophus stramineipes*, Thom.—*Lithocolletis populifoliella*, Tr., N.-Novgorod, vii.1925.
- Microplectron fuscipennis*, Zett.—*Diprion pini*, L., cocoons, Sluzk, 1931 ; *D. sertifer*, Geoff., cocoons, Ukraine, Gorodischi, 1928.
- Sympiesis punctipleurae*, Thom.—From Microlepidoptera, Krasnodar, ix.1930.
- Sympiesis sericeicornis*, Nees—*Lithocolletis* sp., N. Caucasus, vii.1931 ; *Lithocolletis populifoliella*, Tr., Moscow, vii.1932.
- Chrysocharis boops*, Thom.—*Lithocolletis populifoliella*, Tr., Moscow, vii.1932.
- Entedon subovatus*, Thom.—From pupae on leaf of *Pirus malus*, L., N.-Novgorod, vii.1925.
- Pleurotropis (Entedon) metallicus*, Nees (= *epigonus*, Walk.).—*Mayetiola destructor*, Say, puparia, Poltava, 1925.
- Pleurotropis obscuripes*, Ratz.—*Hyp. malinellus*, Z., pupae, with *Tetrastichus euonymellae*, Bché., Poltava, vii.1928 ; *Apanteles fulvipes*, Hald., cocoons, Poltava, v.1929 ; *Apanteles* sp., cocoons, Kazakstan, 1931.
- Crataepus aquisgranensis*, Foerst.—*Orellia flavicauda*, Fabr., larvae, in heads of *Cirsium* sp., Leningrad, viii.1932.
- Tetrastichus atratulus*, Nees—*Cassida nebulosa*, L., larvae, Tomsk, vii.1926, Poltava, vi.1927–29, Ramon, 1930, Ukraine, Lubnui, vii.1931.

- Tetrastichus atrocoeruleus*, Thom.—*Arge rosae*, De Geer, cocoons, N.-Novgorod, x. 1930, Crimea, x.1932.
- Tetrastichus brevicornis*, Nees—*Bruchophagus gibbus*, Boh., Poltava, 1927–30, N.-Novgorod, vii–viii.1925; *Eurytoma onobrychidis*, sp. n., Poltava, vii.1927; *Lithocolletis populifoliella*, Tr. (mines), N.-Novgorod, vii.1925; *Papaver somniferum*, L., fruit, probably on some Cecidomyiid, Poltava, viii.1928; in puparia from galls on *Mentha piperita*, probably of *Asphondylia menthae*, Kieff., Maikop, ix.1931.
- Tetrastichus bruchophagi*, Ash.—*Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, vii.1927–28.
- Tetrastichus cassidarum*, Ratz.—*Cassida nebulosa*, L., larvae, Lubnui, vi.1931.
- Tetrastichus coccinellae*, Kurd.—*Brevicoryne brassicae*, L., Moscow, ix.1925; *Coccinella septempunctata*, L., larvae and pupae, N.-Novgorod, viii.1925; *Chilocorus renipustulatus*, Scr., Maikop, ix.1932.
- Tetrastichus cyclogaster*, Ratz.—*Lithocolletis populifoliella*, Tr. (mines), N.-Novgorod, vii.1924.
- Tetrastichus euonymellae*, Bché.—*Hyponomeuta malinellus*, Z., pupae, *H. padellus*, L., cocoons, Baku, 1930, Poltava, vii.1927–28.
- Tetrastichus flavovarius*, Nees—*Bruchophagus gibbus*, Boh., Tambov, viii.1928, Poltava, ix.1930, N.-Novgorod, vii.1932; *Asphondylia miki*, Wachtl, galls on *Medicago sativa*, L., Poltava, viii.1926; puparia from galls on *Mentha piperita*, probably of *Asphondylia menthae*, Kieff., Maikop, ix.1931.
- Tetrastichus pospelovi*, Kurd.—*Habrocytus tenuicornis*, Foerst., pupae, N.-Novgorod, vi.1925–31.
- Tetrastichus pubescens*, Nees—*Chrysopa* sp., cocoons, Crimea, ix. 1932.
- Tetrastichus rapo*, Walk.—*Apanteles glomeratus*, L., cocoons, N.-Novgorod, ix.1925, Moscow, viii.1927, Ukraine, Lubnui, 1931, Crimea, viii.1932; *Anilastus ebeninus* (Grav.) Thom., cocoons, Rostov on Don, vii.1930; *Anilastus notatus*, Holmgr., cocoons, N.-Novgorod, vii.1925; *Aleyodes testaceus*, Nees, cocoons, Moscow, 1925.
- Tetrastichus roesellae*, Nees—*Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, 1927.
- Tetrastichus tibialis* (Thom.) Kurd.—*Bruchophagus gibbus*, Boh., *Eurytoma onobrychidis*, sp. n., Poltava, 1927.
- Winnemana* sp.—*Lithocolletis populifoliella*, Tr. (mines), N.-Novgorod, vii.1925, Moscow, viii.1932.

SUBFAM. APHELININAE.

- Aphelinus maculicornis*, Masi—*Aspidiotus* sp., Maikop, vi–x.1932.
- Aphelinus mytilaspidis*, De Bar.—*Aspidiotus* sp., Maikop, vi–x.1932.
- Aphelinus varipes*, Foerst.—*Aphis frangulae*, Kalt. (=gossypii. Glov.), Azerbaidjan, vii.1931.
- Azotus pinifoliae*, Mercet—*Aspidiotus ostreaeformis*, Curt., Maikop, vi.1932.
- Centrodora amoena*, Foerst.—*Mayetiola destructor*, Say, puparia, Poltava, 1923; Acridid eggs, Ural region, 1932.
- Coccophagus lecanii*, How —*Coccus hesperidum*, L., Sukhum, ix.1932.
- Prospaltella aurantii*, How.—*Aspidiotus ostreaeformis*, Curt., Maikop, vi.1932.
- Prospaltella similis*, Masi—*Aspidiotus ostreaeformis*, Curt., Maikop, vi.1932.
- Thysanus ater*, Walk.—*Aspidiotus* sp., Maikop, vi–viii.1932.
- Casca chinensis*, How.—*Aspidiotus ostreaeformis*, Curt., Maikop, vi.1932.

SUBFAM. TRICHOGRAMMINAE.

Trichogramma evanescens, Westw.—*Cassida nebulosa*, L., eggs, Poltava, vi.1929;
Chrysops sp., eggs, Leningrad, vii.1930; *Fellia segetum*, Sch., eggs, Ufa, vii.1931;
Phytometra gamma, L., eggs, Ramon, vii.1930; *Loxostege sticticalis*, L., eggs,
 Voronezh, 1932; *Barathra brassicae*, L., eggs, N. Caucasus, 1932.

List of Hosts of Phytophagous Species.

Host.			
<i>Abies</i> sp., seeds	...	...	<i>Megastigmus strobilobius</i> , Ratz.
<i>Bambusa</i> sp., young stems	...	...	<i>Isosoma phyllostachitis</i> , Gah.
<i>Coriandrum sativum</i> , L., fruit	* <i>Systole coriandri</i> , sp. n.
<i>Ficus carica</i> , L., immature fruit	...	...	<i>Blastophaga psenes</i> , L. <i>Philotrypesis caricae</i> , L.
<i>Medicago sativa</i> , L., seeds	...	...	<i>Bruchophagus gibbus</i> , Boh.
<i>Onobrychis sativa</i> , Lam., seeds	* <i>Eurytoma onobrychidis</i> , sp. n.
<i>Prunus domestica</i> , L., fruit	...	...	<i>Eurytoma amygdali</i> , End.
<i>Pirus malus</i> , L., seeds	...	...	<i>Syntomaspis druparum</i> , Boh.
<i>Pistacia mutica</i> , L., fruit	...	...	<i>Megastigmus pistaciae</i> , Walk.
<i>Pistacia vera</i> , L., fruit	...	...	<i>Megastigmus pistaciae</i> , Walk. * <i>Eurytoma plotnikovi</i> , sp. n.
<i>Trifolium pratense</i> , L., seeds	...	...	<i>Bruchophagus gibbus</i> , Boh.
<i>Picea</i> sp., cones	...	...	<i>Torymus azureus</i> , Boh.

List of Hosts of Parasitic Species.

ORTHOPTERA.

Acrididae sp., eggs	<i>Centrodora amoena</i> , Foerst.
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HOMOPTERA.

<i>Aphis frangulae</i> , Kalt (=gossypii, Glov.)		<i>Aphelinus varipes</i> , Foerst.
<i>Brevicoryne brassicae</i> , L.	...	<i>Aphidencyrus aphidivorus</i> , Mayr
		<i>Asaphes vulgaris</i> , Walk.
		<i>Pachyneuron aphidis</i> , Bché.
		<i>Tetrastichus coccinellae</i> , Kurd.
<i>Capitophorus ribis</i> , L.	...	<i>Asaphes vulgaris</i> , Walk.
<i>Aspidiotus ostreaeformis</i> , Curt.	...	<i>Azotus pinifoliae</i> , Mercet
		<i>Casca chinensis</i> , How.
		<i>Chiloneurinus microphagus</i> , Mayr
		<i>Habrolepis zetterstedti</i> , Westw.
		<i>Prospaltella aurantii</i> , How.
		<i>Prospaltella similis</i> , Masi
<i>Aspidiotus</i> sp. on <i>Pirus malus</i> , L., and <i>Prunus domesticus</i> , L.		<i>Aphelinus maculicornis</i> , Masi
		<i>Aphelinus mytilaspidis</i> , De Bar.
		<i>Casca chinensis</i> , How.
		<i>Chiloneurinus microphagus</i> , Mayr
		<i>Thysanus ater</i> , Walk.
<i>Coccus hesperidum</i> , L.	...	<i>Coccophagus lecanii</i> , How.
<i>Eriococcus</i> sp. on wild Gramineae	...	<i>Scutellista aenea</i> , Kurd.

<i>Kermes</i> sp. on <i>Quercus</i> sp.	...	...	<i>Psilophrys longicornis</i> , Walk.
<i>Lecanium persicae</i> (Fabr.) March.	...	...	<i>Blastothrix sericeus</i> , Dalm. <i>Chiloneurus formosus</i> , Boh. <i>Phaenodiscus aeneus</i> , Dalm.
<i>Lecanium prunastri</i> , Sulc, on <i>Prunus divaricata</i> , Ehrh.			<i>Cerapterocerus mirabilis</i> , Westw. <i>Phaenodiscus aeneus</i> , Dalm.
<i>Lecanium</i> sp.	...	...	<i>Encyrtus tessellatus</i> , Dalm.
<i>Phaenococcus aceris</i> , Sign.	...	...	<i>Anagyrus bohemani</i> , Westw.
<i>Physokermes coryli</i> , L.	...	...	<i>Cerapterocerus mirabilis</i> , Westw. <i>Encyrtus ferrugineus</i> , Nees <i>Phaenodiscus aeneus</i> , Dalm.
<i>Pulvinaria betulae</i> , L.	...	...	<i>Encyrtus ferrugineus</i> , Nees <i>Phaenodiscus aeneus</i> , Dalm.

COLEOPTERA.

<i>Anthonomus pomorum</i> , L., larvae and pupae			<i>Habrocytus tenuicornis</i> , Foerst.
<i>Anthrribus nebulosus</i> , Foerst., in scales of <i>Lecanium corni</i> , Bouché			<i>Eupelmus urozonus</i> , Dalm.
<i>Apion</i> spp. in heads of <i>Trifolium pratense</i> , L.			<i>Spintherus linearis</i> , Walk.
<i>Bruchus rufimanus</i> , Boh.	...	...	<i>Bruchobius laticeps</i> , Ash. <i>Eupelmus microzonus</i> , Foerst.
<i>Calandra granaria</i> , L.	...	...	<i>Lariophagus distinguendus</i> , Foerst.
<i>Cassida nebulosa</i> , L., eggs	...	...	<i>Trichogramma evanescens</i> , Westw.
larvae	...	...	<i>Tetrastichus atratulus</i> , Nees <i>Tetrastichus cassidarum</i> , Ratz.
pupae	...	...	<i>Chalcis vitripennis</i> , Foerst.
<i>Chilocorus renipustulatus</i> , Scr., larvae	...	...	<i>Tetrastichus coccinellae</i> , Kurd.
<i>Coccinella septempunctata</i> , L., larvae	...	...	<i>Homalotylus flaminus</i> , Dalm. <i>Pachyneuron syrphi</i> , Ash.
larvae and pupae			<i>Tetrastichus coccinellae</i> , Kurd.
Scolytidae in <i>Picea</i> sp.	...	...	<i>Rhopalicus suspensus</i> , Ratz. <i>Roptrocercus xylophagorum</i> , Ratz.
<i>Stegobium (Sitotroga) paniceum</i> , L.	...	...	<i>Lariophagus distinguendus</i> , Foerst.
<i>Tychius medicaginis</i> , Bris.	...	...	<i>Eupelmus microzonus</i> , Foerst. <i>Habrocytus microgasteris</i> (Bché.), Kurd.

NEUROPTERA.

<i>Chrysopa</i> sp., cocoons	<i>Dibrachys boucheanus</i> , Ratz. <i>Tetrastichus pubescens</i> , Nees
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DIPTERA.

<i>Asphondylia miki</i> , Wachtl	<i>Eurytoma dentata</i> , Mayr <i>Pseudocatolaccus asphondyliae</i> , Masi <i>Tetrastichus flavovarius</i> , Nees
<i>Asphondylia menthae</i> , Kieff.? on <i>Mentha piperita</i>			<i>Sphegigaster aeneicornis</i> , Ratz. <i>Tetrastichus brevicornis</i> , Nees

<i>Chlorops pumilionis</i> , Bjerk. (= <i>taeniopus</i> Meig.) puparia	...	...	...	<i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Eupelmus vesicularis</i> , Retz. <i>Micromelus rufomaculatus</i> , Walk. <i>Stenomalus laetus</i> , Rush. <i>Stenomalus micans</i> , Ol.
<i>Chrysops</i> sp., eggs	...	...	...	<i>Trichogramma evanescens</i> , Westw.
<i>Larvaevora noctuarum</i> , Rond., from cocoons of <i>Loxostege sticticalis</i> , L.				<i>Perilampus nitens</i> , Walk.
<i>Lasiosina cinctipes</i> , Meig., puparia	...			<i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Micromelus rufomaculatus</i> , Walk.
<i>Mayetiola destructor</i> , Say, puparia	...			<i>Centrodora amoena</i> , Foerst. <i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Eupelmus vesicularis</i> , Retz. <i>Eupteromalus arvensis</i> , Kurd. <i>Meraporus crassicornis</i> , Kurd. <i>Merisus destructor</i> , Say <i>Micromelus rufomaculatus</i> , Walk. <i>Pleurotropis metallicus</i> , Walk. <i>Tetrastichus tibialis</i> (Thom.), Kurd.
<i>Meromyza saltatrix</i> , L., puparia	...	...	...	<i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Eupelmus vesicularis</i> , Retz. <i>Micromelus rufomaculatus</i> , Walk. <i>Stenomalus micans</i> , Ol.
<i>Orellia flavicauda</i> , Fabr., puparia from heads of <i>Cirsium</i> sp.				<i>Crataepus aquisgranensis</i> , Foerst.
<i>Oscinosoma frit</i> , L., puparia	...	...	...	<i>Eupteromalus arvensis</i> , Kurd. <i>Halticoptera petiolata</i> , Thom. <i>Micromelus rufomaculatus</i> , Walk. <i>Trichomalus cristatus</i> , Foerst.
Syrphidae, puparia	...	...	...	<i>Chiloneurus formosus</i> , Boh. <i>Microterys aeruginosus</i> , Dalm. <i>Pachyneuron syrphi</i> , Ash.
Tachinidae, puparia	...	...	...	<i>Chalcis minuta</i> , L. <i>Perilampus violaceus</i> , Fabr.
Tachinid puparia from Acrididae	...			<i>Chalcis fonscolombei</i> , Duf.
Tachinid puparia from <i>Pyrausta nubilalis</i> , Hb.				<i>Perilampus auratus</i> , Panz. <i>Stenomalus muscarum</i> , Thom.
Tachinid puparia from <i>Carpocapsa pomonella</i> , L.				<i>Dibrachys boucheanus</i> , Ratz.
<i>Acanthiophilus helianthi</i> , Schr., in heads of <i>Carthamus tinctorius</i> , L.				<i>Ormyrus punctiger</i> , Westw. <i>Torymus quercinus</i> , Boh.
Cecidomyiid larvae in seed-pods of <i>Camelina sativa</i> , L.				<i>Pseudotorymus militaris</i> , Boh. <i>Pseudotorymus pannonicus</i> , Mayr
Cecidomyiid larvae in fruit of <i>Papaver somniferum</i> , L.				<i>Pseudotorymus militaris</i> , Boh. <i>Tetrastichus brevicornis</i> , Nees

HYMENOPTERA.

<i>Ageniaspis fuscicollis</i> , Dalm., cocoons in larvae of <i>H. malinellus</i> , Z.	<i>Dibrachys boucheanus</i> , Ratz.
<i>Aleyodes testaceus</i> , Nees, cocoons in larvae of <i>Dicranura</i> sp.	<i>Tetrastichus rapo</i> , Walk.
<i>Anilastus ebeninus</i> (Grav.) Thom., cocoons	<i>Dibrachys boucheanus</i> , Ratz. <i>Tetrastichus rapo</i> , Walk.
<i>Anilastus notatus</i> , Holm., cocoons ...	<i>Tetrastichus rapo</i> , Walk.
<i>Anilastus</i> sp., cocoons ...	<i>Catolaccus cavigena</i> , Thom.
<i>Apanteles fulvipes</i> , Hald., cocoons ...	<i>Dibrachys boucheanus</i> , Ratz. <i>Eurytoma appendigaster</i> , Dalm. <i>Pleurotropis obscuripes</i> , Ratz.
<i>Apanteles glomeratus</i> , L., cocoons ...	<i>Catolaccus ater</i> , Ratz. <i>Dibrachys boucheanus</i> , Ratz. <i>Eurytoma appendigaster</i> , Dalm. <i>Eurytoma strigifrons</i> , Thom. <i>Habrocytus microgasteris</i> (Bché.), Kurd. <i>Tetrastichus rapo</i> , Walk.
<i>Aphelinus mali</i> , Hald., in <i>Eriosoma lanigerum</i> , Hausm.	<i>Asaphes vulgaris</i> , Walk. <i>Pachyneuron aphidis</i> , Bché.
<i>Arge rosae</i> , DeGeer, cocoons ...	<i>Tetrastichus atrocoeruleus</i> , Thom.
<i>Athalia colibri</i> , Christ, cocoons ...	<i>Perilampus italicus</i> , Fabr.
<i>Biorrhiza pallida</i> , Ol., galls on <i>Quercus</i> sp.	<i>Decatoma biguttata</i> , Swed. <i>Eupelmus spongipartus</i> , Foerst.
<i>Bruchophagus gibbus</i> , Boh. ...	<i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Eupelmus vesicularis</i> , Retz. <i>Habrocytus medicaginis</i> , Gah. <i>Liodontomerus perplexus</i> , Gah. <i>Liodontomerus secundus</i> , Gah. <i>Tetrastichus brevicornis</i> , Nees <i>Tetrastichus bruchophagi</i> , Ash. <i>Tetrastichus flavovarius</i> , Nees <i>Tetrastichus roesellae</i> , Nees <i>Tetrastichus tibialis</i> (Thom.), Kurd.
<i>Canidia curculionis</i> , Thom., cocoons ...	<i>Dibrachys boucheanus</i> , Ratz.
<i>Cephus pygmaeus</i> , L., cocoons ...	<i>Arthrolysis scabriculus</i> , Nees <i>Eupelmus atropurpureus</i> , Dalm.
<i>Diprion pini</i> , L. cocoons ...	} <i>Microplectron fuscipennis</i> , Zett.
<i>Diprion sertifer</i> , Geoff., cocoons ...	
<i>Eurytoma onobrychidis</i> , sp. n. ...	<i>Eupelmus atropurpureus</i> , Dalm. <i>Eupelmus microzonus</i> , Foerst. <i>Eupelmus vesicularis</i> , Retz. <i>Habrocytus medicaginis</i> , Gah. <i>Liodontomerus perplexus</i> , Gah. <i>Tetrastichus brevicornis</i> , Nees <i>Tetrastichus bruchophagi</i> , Ash. <i>Tetrastichus roesellae</i> , Nees <i>Tetrastichus tibialis</i> (Thom.), Kurd.
<i>Habrocytus tenuicornis</i> , Foerst., pupae	<i>Tetrastichus pospelovi</i> , Kurd.

<i>Rhodites rosae</i> , L.	...	...	...	<i>Eurytoma rosae</i> , Nees
				<i>Habrocytus bedeguaris</i> , Thom.
				<i>Oligosthenus stigma</i> , Fab.
				<i>Torymus bedeguaris</i> , L.
Cynipid galls on <i>Rubus idaeus</i> , L.	...			<i>Torymus macropterus</i> , Walk.
Ichneumonid cocoons from <i>Hypon. malinellus</i> , Z.				<i>Dibrachys boucheanus</i> , Ratz.
				<i>Habrocytus microgasteris</i> (Bché.), Kurd.
Ichneumonid cocoons from <i>Pyrausta nubilalis</i> , Hb.				<i>Dibrachys boucheanus</i> , Ratz.
Ichneumonid cocoons from <i>Heliothis peltigera</i> , Sch.				<i>Chalcis rugulosa</i> , Foerst.
<i>Isosoma</i> sp., from <i>Agropyrum repens</i> , L.				<i>Decatoma mellea</i> , Walk.
				<i>Homoporus luniger</i> , Nees
<i>Isosoma</i> sp., from <i>Phleum pratense</i> , L.	...			<i>Eupelmus linearis</i> , Foerst.

LEPIDOPTERA.

<i>Acalla variegana</i> , Sch	...	...	...	<i>Chalcis intermedia</i> , Nees
<i>Aporia crataegi</i> , L., pupae	...	...	...	<i>Chalcis femorata</i> , Panz.
				<i>Chalcis intermedia</i> , Nees
				<i>Dibrachys boucheanus</i> , Ratz.
				<i>Monodontomerus aereus</i> , Walk.
				<i>Monodontomerus dentipes</i> , Boh.
<i>Barathra brassicae</i> , L., larvae	...	...	...	<i>Euplectrus bicolor</i> , Swed.
<i>Carpocapsa pomonella</i> , L., cocoons	...	...	...	<i>Dibrachys boucheanus</i> , Ratz.
<i>Cerostoma persicella</i> , Sch.	...	...	...
<i>Cirphis unipuncta</i> , Hw., larvae	...	...	...	<i>Euplectrus bicolor</i> , Swed.
<i>Depressaria depressiella</i> , Hb., pupae	...	...	...	<i>Chalcis rugulosa</i> , Foerst.
<i>Euproctis chrysorrhoea</i> , L., cocoons	...	...	...	<i>Dibrachys boucheanus</i> , Ratz.
				<i>Eupteromalus nidulans</i> , Thom.
<i>Feltia (Agrotis) segetum</i> , Sch., eggs	...	...	...	<i>Trichogramma evanescens</i> , Westw.
<i>Hyponomeuta euonymellus</i> , L., larvae	...	...	...	<i>Ageniaspis fuscicollis</i> , Dalm.
<i>Hyponomeuta malinellus</i> , Z., larvae	...	...	...	<i>Ageniaspis fuscicollis</i> , Dalm.
pupae and cocoons				<i>Dibrachys boucheanus</i> , Ratz.
				<i>Elasmus flabellatus</i> , Westw.
				<i>Pleurotropis obscuripes</i> , Ratz.
<i>Hyponomeuta padellus</i> , L., larvae	...	...	...	<i>Tetrastichus euonymellae</i> , Bché.
cocoons	...	...	...	<i>Ageniaspis fuscicollis</i> , Dalm.
				<i>Elasmus flabellatus</i> , Westw.
				<i>Tetrastichus euonymellae</i> , Bché.
<i>Lithocolletis populifoliella</i> , Tr.	...	...	...	<i>Chrysocharis boops</i> , Thom.
				<i>Eulophus longulus</i> , Zett.
				<i>Eulophus stramineipes</i> , Thom.
				<i>Sympiesis sericeicornis</i> , Nees
				<i>Tetrastichus brevicornis</i> , Nees
				<i>Tetrastichus cyclogaster</i> , Ratz.
				<i>Winnemana</i> sp.
<i>Lithocolletis</i> sp.	...	...	...	<i>Sympiesis sericeicornis</i> , Nees
<i>Loxostege sticticalis</i> , L., eggs	...	...	...	<i>Trichogramma evanescens</i> , Westw.
<i>Papilio machaon</i> , L., pupae	...	...	...	<i>Pteromalus puparum</i> , Swed.
<i>Phytometra (Plusia) gamma</i> , L., eggs	...	...	...	<i>Trichogramma evanescens</i> , Westw.
larvae	...	...	...	<i>Euplectrus bicolor</i> , Swed.
				<i>Litomastix truncatellus</i> , Dalm.
pupae	...	...	...	<i>Catolaccus ater</i> , Ratz.

<i>Pieris brassicae</i> , L., eggs	...	...	<i>Trichogramma evanescens</i> , Westw.
pupae	...	...	<i>Pteromalus puparum</i> , Swed.
<i>Pieris daplidicae</i> , L., pupae	...	...	<i>Chalcis femorata</i> , Panz.
<i>Pieris rapae</i> , L., pupae	...	...	<i>Chalcis intermedia</i> , Nees
			<i>Hockeria bispinosa</i> , Walk.
			<i>Pteromalus puparum</i> , Swed.
<i>Polychrosis botrana</i> , Sch.	...	...	<i>Hockeria bispinosa</i> , Wlk.
<i>Porthetria (Ocneria) dispar</i> , L., eggs	...	...	<i>Anastatus bifasciatus</i> v. <i>disparis</i> , Rush.
<i>Prays oleaellus</i> , Fabr.	...	...	<i>Elasmus flabellatus</i> , Westw.
<i>Pygaera anachoreta</i> , F., pupae	...	...	<i>Cratotechus longicornis</i> , Thom.
<i>Pyrameis cardui</i> , L., pupae	...	...	<i>Pteromalus puparum</i> , Swed.
<i>Sparganothis pilleriana</i> , Sch.	...	...	<i>Chalcis intermedia</i> , Nees
<i>Vanessa io</i> , L., pupae	...	...	<i>Pteromalus puparum</i> , Swed.
<i>Vanessa urticae</i> , L., pupae	...	...
<i>Vanessa xanthomelas</i> , Esp., pupae	...	...
Noctuid larvae on cabbage	...	...	<i>Eulophus pectinicornis</i> , L.

APPENDIX.

Subfamily EURYTOMINAE.

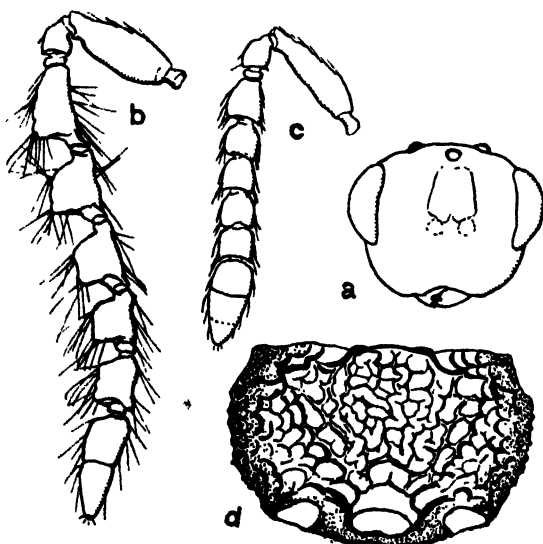
***Eurytoma onobrychidis*, sp. n. (fig. 1).**

Fig. 1. *Eurytoma onobrychidis*, sp. n. : a, head (\times about 22) ; b, male antenna (\times 40) ; c, female antenna (\times 40) ; d, propodeon (\times 40).

Female. Black ; tip of ovipositor sheath, knees of all legs, front tibiae, distal ends of middle and hind tibiae and all tarsi, except last joints, brownish yellow ; ventral surface of front tibiae with a longitudinal dark stripe. Wings hyaline, venation light brownish-yellow. Head and thorax with deep, thimble-like punctures and white pubescence. Face wrinkled from inner eye-margin to base of mandibles. Propodeon wrinkled-reticulate. Abdomen egg-shaped, shining, smooth, its 4th segment

(except petiolus) with a transverse row of sparse hairs in the middle. Antennae dark, tip of pedicel and ring-joint lighter. Pedicel longer than wide; first funicle joint the longest, others equal in length, club as long as $2\frac{1}{2}$ preceding joints. Length 2.5-3.5 mm.

Male. Similar to female in colour, sculpture and pilosity. Abdomen oval, its petiolus not longer than the hind coxae. Antennae black, ring-joint brownish. Funicle joints short, pedunculate, with 2 whorls of long hairs equal in length to those of middle joints. First joint the longest, others equal in length. Length 2-3 mm.

The species was reared at the Poltava Agricultural Experiment Station in 1927-28 from seed-pods of *Onobrychis sativa*, Lam. The larva wholly destroyed the seed, but infestation was not severe during the season.

***Eurytoma plotnikovi*, sp. n. (fig. 2).**

Female. Head black, thorax and abdomen reddish-brown, more or less blackened. In dark-coloured specimens the propodeon and even the scutellum are black. Legs, venation of front wing, scape and part of pedicel of antennae yellow. Flagellum brownish, shortly pilose. Wings hyaline. Head and thorax with thimble-like shallow punctures and white pubescence, extremely dense on face. Propodeon reticulated with a narrow longitudinal groove in the middle. Abdomen egg-shaped shining, finely-punctate on sides. First funicle joint $1\frac{1}{2}$ times as long as second, others nearly equal in length. Club as long as two preceding joints. Length 4.5-5 mm.

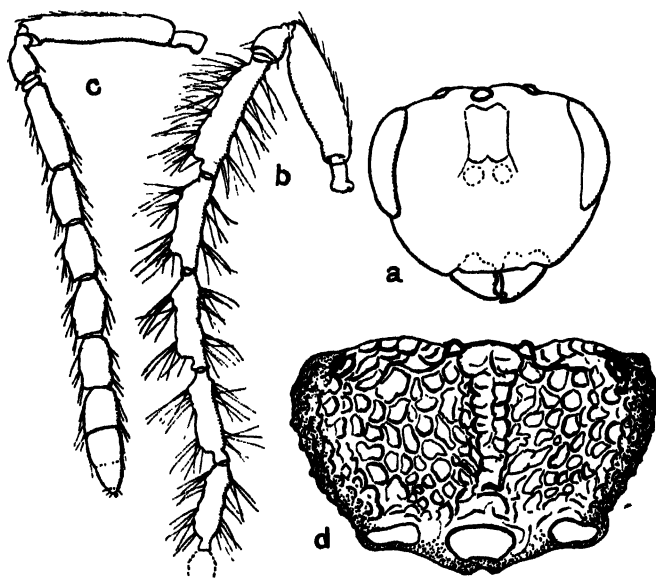


Fig. 2. *Eurytoma plotnikovi*, sp. n.: a, head (\times about 22); b, male antenna (\times 40); c, female antenna (\times 40); d, propodeon (\times 40).

Male. In sculpture and pilosity similar to female. Black, legs yellow, coxae more or less black at base. Abdomen shortly ovate, pediculus more than $1\frac{1}{2}$ as long as hind coxae. Funicle joints long, shortly pedunculate, with not long hairs set in whorls. First joint the longest, the remainder becoming shorter towards the apex. Club broken off in all the cases.

Males seem to be rare. For 150♀♀ there were only 3♂♂. The species was reared from fruit of *Pistacia vera*, L., gathered in Turcomania (Kushka) during the autumn of 1930 by V. T. Gorbunova.

***Systole coriandri*, sp. n. (fig. 3).**

Female. Tar-black. Mouth-border, scape of antennae, tip of ovipositor sheath, inner part of front coxae, apical parts of femora, all tibiae and tarsi (except the dark last joints) and venation of front wing brownish yellow. Basal parts of the four anterior and nearly the whole of the hind femora blackened. Flagellum brownish. Head and thorax with white pubescence, finely punctate; front part of mesonotum slightly wrinkled. Propodeon irregularly reticulate and wrinkled. Abdomen shining and smooth, elongate oval. Pedicel longer than first funicle joint, which is

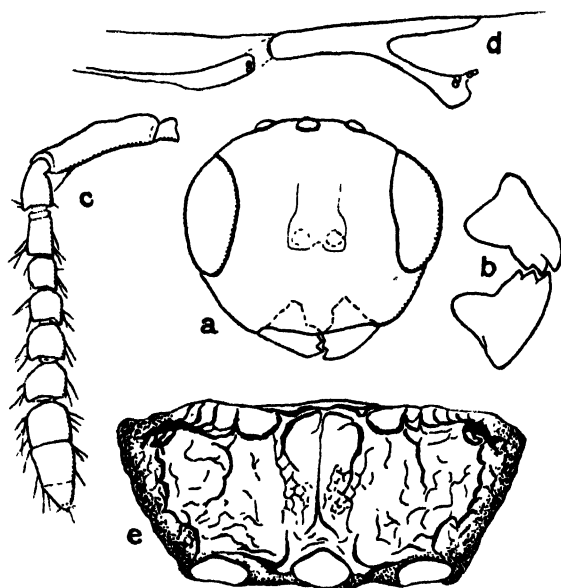


Fig. 3. *Systole coriandri*, sp. n.: a, head ($\times 40$); b, mandibles (\times about 67); c, female antenna (\times about 67); d, venation of forewing (\times about 67); e, propodeon (\times about 67).

slightly longer and narrower than second; the following joints gradually broadened towards the apical end and nearly the same length; club as long as three preceding joints. Length 1.5–2.5 mm. Male unknown. The larva destroys the seeds of *Coriandrum sativum*, L.

In several hundreds of specimens from North Caucasus only females were found.

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st October and 31st December, 1933 :—

AGRICULTURAL OFFICER, QUETTA :—3 Diptera, 27 Coleoptera, 2 Lepidoptera, 5 Rhynchota and 2 exuviae ; from Baluchistan.

Mr. A. M. ALSTON :—6 Diptera, 50 Parasitic Hymenoptera and 30 cocoons ; from South Africa.

Mr. E. BALLARD, Government Entomologist :—16 Diptera, 39 Coleoptera, 12 Hymenoptera, 14 Lepidoptera, 28 Rhynchota, 3 Dermaptera, and 100 Anoplura ; from Palestine.

Dr. H. F. BARNES, Rothamsted Experimental Station :—7 Parasitic Hymenoptera ; from England.

Mr. H. J. BRÉDO :—5 Diptera and 4 pupa-cases, 8 Lepidoptera and 6 pupa-cases, and 6 Rhynchota ; from the Belgian Congo.

Mr. H. BRITTEN :—59 Parasitic Hymenoptera ; from England.

BURMA-SIAM RICE COMPANY, LONDON :—77 Coleoptera ; from England.

Prof. P. A. BUXTON, London School of Tropical Medicine :—10 Culicidae, 84 Tabanidae, 4 Hippoboscidae, 6 *Auchmeromyia*, 7 *Cordylobia*, 30 other Diptera, 18 Lepidoptera, 38 Rhynchota, 94 Orthoptera, 5 Dermaptera, 60 Planipennia, 4 Ephemeridae, and 6 Trichoptera ; from Nigeria.

CHIEF ENTOMOLOGIST, PRETORIA :—50 Parasitic Hymenoptera ; from South Africa.

CHIEF VETERINARY OFFICER, BURAO :—11 Coleoptera ; from British Somaliland.

Mr. G. H. CORBETT, Government Entomologist :—11 Diptera, 27 Coleoptera, 300 Parasitic Hymenoptera, 23 Lepidoptera, 30 Isoptera, 4 species of Coccidae, 3 species of Aphidae, 16 other Rhynchota, 2 Orthoptera, and 200 Mites ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—496 Coleoptera ; from Kenya Colony.

Mr. G. S. COTTERELL, Government Entomologist :—5 Diptera, 37 Coleoptera, 4 Parasitic Hymenoptera, 42 Lepidoptera, 1 species of Coccidae, and 2 Orthoptera ; from the Gold Coast.

Mr. A. CUTHBERTSON, Assistant Entomologist :—21 Diptera and 6 Coleoptera ; from Southern Rhodesia.

Mr. R. C. M. DARLING, Locust Investigator :—87 Orthoptera ; from the Sudan.

Mr. A. P. DODD :—2 tubes of Eriophyidae ; from Queensland.

Mr. V. H. W. DOWSON :—1 Tingid ; from Iraq.

Dr. H. L. DOZIER :—8 species of Aleurodidae ; from the Belgian Congo.

Mr. P. R. DUPONT, Director of Agriculture :—50 Scolytidae and 50 early stages, 11 Lepidoptera and 50 early stages, and 10 Delphacidae ; from the Seychelles.

Mr. J. C. M. GARDNER, Systematic Entomologist :—85 Tachinidae, 128 Coleoptera, 65 Parasitic Hymenoptera and 19 cocoons ; from the United Provinces, India.

Mr. S. GARTHSIDE :—3 Diptera, 2 Coleoptera, 7 Parasitic Hymenoptera, 2 Lepidoptera, 7 Rhynchota, and 4 Chrysopidae ; from England.

Mr. F. D. GOLDING, Government Entomologist :—6 Coleoptera, 5 Lepidoptera, 1 species of Coccidae, 8 other Rhynchota, and 18 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—3 Noctuidae and 200 Collembola ; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—111 Parasitic Hymenoptera, 9 Lepidoptera, and 5 species of Coccidae ; from the Punjab, India.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—76 Coleoptera and 9 Rhynchota ; from Uganda.

Mr. E. HARGREAVES, Government Entomologist :—15 Culicidae, 43 other Diptera, 101 Coleoptera, 24 Parasitic Hymenoptera, 11 other Hymenoptera, 162 Lepidoptera, 200 Thysanoptera, 3 species of Coccidae, 22 other Rhynchota, 21 Orthoptera, 4 Planipennia, 15 Ticks, and 4 tubes of Parasitic Worms ; from Sierra Leone.

Mr. G. H. E. HOPKINS, Medical Entomologist :—2 Diptera, 33 Coleoptera, 3 Parasitic Hymenoptera, 70 other Hymenoptera, and 298 Lepidoptera ; from Uganda.

Dr. G. E. HUTCHINSON :—9 Curculionidae ; from North India.

Dr. J. C. HUTSON, Government Entomologist :—4 Curculionidae ; from Ceylon.

IMPERIAL ENTOMOLOGIST, PUSA :—10 Diptera, 160 Coleoptera, 11 Hymenoptera, 5 Lepidoptera, 58 Rhynchota, and 2 Orthoptera ; from India.

INDEPENDENT BIOLOGICAL LABORATORIES, TEL-AVIV :—43 Parasitic Hymenoptera and 27 other Hymenoptera ; from Palestine.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—65 Coleoptera, 67 Lepidoptera, and 96 Rhynchota ; from the Dutch East Indies.

Dr. H. C. JAMES :—2 Culicidae, 304 other Diptera, 322 Coleoptera, 29 Parasitic Hymenoptera, 109 other Hymenoptera, 3 Lepidoptera, 186 Rhynchota, 7 Orthoptera, 4 Planipennia, 2 Ephemeridae, 2 Trichoptera, and 2 Spiders ; from Kenya Colony.

Mr. C. B. R. KING, Tea Research Institute :—6 Diptera and 21 Parasitic Hymenoptera ; from Ceylon.

Mr. R. A. LEVER, Assistant Entomologist :—43 Culicidae, 11 Tabanidae, 340 other Diptera, 552 Coleoptera and 30 larvae, 77 Parasitic Hymenoptera, 24 other Hymenoptera, 53 Lepidoptera and 2 pupa cases, 250 Isoptera, 1 species of Coccidae, 220 other Rhynchota, 52 Orthoptera, 6 Dermaptera, 6 Planipennia, 3 Odonata, 50 Mites, 2 Spiders, and 3 Crustacea ; from the Solomon Islands.

Mr. D. J. LEWIS, London School of Tropical Medicine :—155 Diptera, 2 Coleoptera, 2 Parasitic Hymenoptera, 8 other Hymenoptera, 10 Rhynchota, and 3 *Bittacus* ; from Nigeria.

Dr. E. A. LEWIS, Veterinary Entomologist :—18 Tabanidae, 223 *Glossina*, 3 *Auchmeromyia*, 25 *Cordylobia* and 6 larvae, 39 Hippoboscidae, 3 Oestridae and 82 early stages, 172 other Diptera and 35 larvae, 2 Coleoptera, 2 Parasitic Hymenoptera, 5 other Hymenoptera, 8 Lepidopterous early stages, 18 Orthoptera, 2 Odonata, and 14,000 Ticks ; from Kenya Colony.

Mr. J. E. M. LLOYD :—20 Parasitic Hymenoptera ; from Tanganyika Territory.

Mr. H. MANEVAL :—71 Parasitic Hymenoptera and 30 cocoons ; from France.

Prof. F. J. MEGGITT :—4 Diptera, 23 Coleoptera, 24 Rhynchota, and 48 Orthoptera from Burma.

Dr. D. MILLER, Cawthron Institute :—25 Jassidae ; from New Zealand.

Mr. H. M. MORRIS, Government Entomologist :—45 Parasitic Hymenoptera and 110 Lepidoptera ; from Cyprus.

Mr. A. MOUTIA, Assistant Entomologist :—4 Diptera, 90 Parasitic Hymenoptera, 140 Isoptera, and 9 species of Aphidae ; from Mauritius.

Mr. R. W. MUNGOMERY :—2 species of Coccidae ; from Queensland.

MUSÉE DU CONGO BELGE, TERVUEREN :—3 Diptera, 26 Coleoptera, and 2 Parasitic Hymenoptera ; from the Belgian Congo.

MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS :—19 Curculionidae ; from Portuguese East Africa.

Mr. F. B. NOTLEY, Assistant Entomologist :—1 species of Coccidae and 36 Rhynchota ; from Kenya Colony.

Mr. J. OGILVIE :—12 Hymenoptera ; from Barbados.

PACIFIC ENTOMOLOGICAL SURVEY :—205 Coleoptera and 30 larvae, and 4 Lepidopterous pupae ; from the Marquesas Islands.

Mr. R. PAILLOT :—3 Parasitic Hymenoptera ; from France.

Mr. R. W. PAINE, Entomologist, Coconut Committee :—19 Scolytidae and 60 early stages, 60 Formicidae, and 2 Spiders ; from the Fiji Islands.

Rev. O. PIEL :—91 Parasitic Hymenoptera ; from China.

Mr. Y. R. RAO, Locust Investigator :—14 Coleoptera, 13 Hymenoptera, 17 Lepidoptera, 15 Orthoptera, and 9 Planipennia ; from Baluchistan.

Dr. P. REGNIER :—30 Parasitic Hymenoptera ; from Morocco.

Dr. A. KEYNE :—1 species of Aleurodidae : from Celebes.

Dr. W. E. RIPPER :—24 Parasitic Hymenoptera and 6 cocoons : from Austria.

Dr. E. RIVNAY :—72 Coleoptera, 26 Hymenoptera, 27 Lepidoptera, 75 Rhynchota, 34 Orthoptera, 4 Planipennia, and 5 Odonata ; from Palestine.

Mr. E. R. SPEYER :—25 Collembola ; from England.

Mr. F. A. SQUIRE, Government Entomologist : 7 Psychodidae, 2 Coleoptera, 37 Formicidae, 2 Lepidoptera, 2 species of Coccidae, and 2 species of Aphidae ; from British Guiana.

Miss M. STEELE :—12 Tabanidae, 12 Hippoboscidae, 644 other Diptera and 2 larvae, 2,107 Coleoptera, 97 Parasitic Hymenoptera, 806 other Hymenoptera, 1,788 Lepidoptera, 7 Isoptera, 80 Thysanoptera, 613 Rhynchota, and 27 early stages, 194 Orthoptera, 11 Dermaptera, 21 Planipennia and 7 larvae, 145 Odonata, 2 Trichoptera, 1,000 Collembola, 6 Mites, 338 Spiders, 18 Scorpions, 3 Chelifers, 3 Centipedes, 16 Millipedes, and 7 Crustacea ; from the Sudan.

Dr. P. TCHORBADJIEV : 32 Coleoptera and 5 larvae, 90 Parasitic Hymenoptera, 23 other Hymenoptera, 13 Rhynchota, and 145 Orthoptera ; from Bulgaria.

UNILEVER, LTD., LONDON :—15 Coleoptera ; from Burma.

Mr. G. C. VARLEY :—300 Parasitic Hymenoptera ; from England.

Mr. R. VEITCH, Chief Entomologist :—9 Parasitic Hymenoptera ; from Queensland.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—33 Culicidae, 13 Tabanidae, 4 *Auchmeromyia*, 35 *Phlebotomus*, 6 Simuliidae, 40 other Diptera, 99 Coleoptera, 160 Parasitic Hymenoptera, 54 Lepidoptera, and 31 slides of Aphidae ; from the Sudan.

Mr. W. E. WHITEHEAD : 26 slides of Mallophaga , from Canada and Barbados.

Mr. F. X. WILLIAMS :—12 Psychodidae and 150 Chironomidae ; from Hawaii.

ON SOME COLEOPTEROUS LARVAE FROM UGANDA.

By J. C. M. GARDNER.

Forest Research Institute, Dehra Dun, U.P., India.

(PLATE VI.)

Mr. H. Hargreaves, Government Entomologist, Uganda, has sent me identified larvae of several species of beetles. I now describe those which are of economic importance.

The characters of the families and many subfamilies of Coleopterous larvae are very exactly defined by Böving and Craighead (*Entomologica americana*, **11**, 1931) and I have not considered it necessary to repeat them.

The drawings are by Jung Bahadur Singh.

Family LYMEXYLONIDAE.

Atractocerus brevicornis, Linn. (Pl. vi, fig. 15).

This larvae closely resembles the Indian species *A. emarginatus*, Cast.,* and *A. reversus*, Walk.† The three species are separable by the shape and arrangement of the asperities which occur in a more or less triangular patch on the blunt apex of the dorsally produced ninth segment. In *brevicornis* (fig. 15) the asperities on the two lateral sides of the triangle are all rather large and strongly transverse, the apical asperity hardly larger than the other marginal asperities (whereas in *reversus* the apical asperity is distinctly larger); the discal asperities are simple points, not transverse (thus resembling *reversus* and differing from *emarginatus*, in which the small discal asperities are transverse). The head is castaneous with a pale stripe on each side as in *emarginatus*. Length of larva about 45 mm.

Two larvae ex "Nkoba" log, Uganda (G. D. H. Carpenter).

Family CHRYSOMELIDAE.

Characters distinguishing Eumolpine larvae from other Chrysomelid subfamilies are defined by Böving and Craighead (1931, p. 64, etc.). The epicranial suture is long. Ocelli absent. Labrum well developed and free. Mandible with two or three distal teeth. Maxillary palp with three or four segments. Eighth abdominal segment not terminal. Claw (tarsungulus) long, slender, without pulvillus.

Syagrus calcaratus, F. (Pl. vi, figs. 5-9; text-fig. 1).

Larva (fig. 5): Body moderately stout, of nearly equal width but somewhat narrower at extremities; slightly curved. Skin soft, with a granulate appearance. Many of the setae stiff and bristle-like, especially on ventral surface. Length about 10 mm.

Head-capsule testaceous brown, width (1.4 mm.) slightly greater than length, sides curved; a small but distinct posterior emargination is present. Frons transverse, with pale, rather faint, sutures. Antenna (fig. 6) small, with soft basal skin and two segments; basal segment about as wide as long; second cylindrical, about twice as long as wide, bluntly rounded at apex, shorter than and about one-fourth as wide as basal segment; in addition the basal segment bears a soft-skinned appendage which

* Gardner. Ind. For. Rec. **12**, 1926, p. 280.

† Gardner. Ind. For. Rec. **14**, 1929, p. 111.

is slightly longer than, and at least twice as wide as, the true apical segment, tapering weakly to the blunt apex. Clypeus large. Labrum transverse, anterior margin rounded, posterior margin rather widely produced under clypeus; with six longer setae on disc and a pair of small apical setae. Epipharynx with a pair of longitudinal rods with a transverse bridge posteriorly; anterior margin with six setae (decreasing in size inwardly) and with two large flattened setae on each side; median zone with dense hair-like structures. Mandible (fig. 8) somewhat flattened, the apex narrowed and bidentate, the upper margin of the concave inner face angulate near middle. Maxillary palp (text-fig. 1) with soft unpigmented palpiger and four brownish segments: the first moderately transverse, the second more strongly transverse, the third longer, about as long as wide, the fourth rather shorter and much narrower than third. Maxillary mala of about equal width, broadly rounded apically. Labium (text-fig. 1) fleshy, the prementum limited posteriorly by a widely U-shaped brown line; labial palp with a single weakly tapering segment which is about twice as long as wide and distinctly longer than apical segment of maxillary palp. Hypopharynx

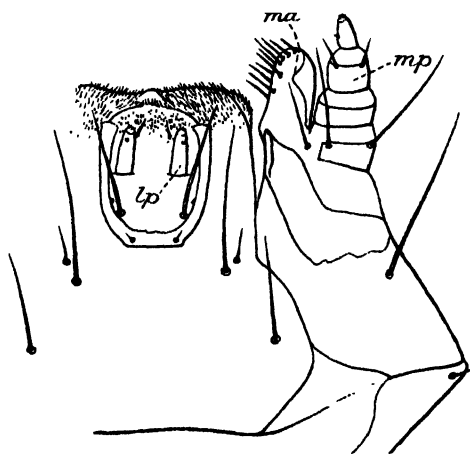


Fig. 1. Larva of *Syagrus calcaratus*, F.: ventral mouth-parts; *lp*, labial palp; *ma*, maxillary mala, *mp*, maxillary palp.

fleshy, supported by two longitudinal rods. Pronotal plate testaceous, shining, moderately transverse. Anterior abdominal terga with three transverse folds, the first fold without setae, the second with two (small), the third with four, setae, each arising from a small shining plate. Above the spiracle a group of three setae (one small) and slightly higher, a single seta. Posterior margin of ninth tergum with four small rounded lobes. Epipleura roundly protuberant, shining, with several setae. Abdominal sterna with paired median plates and a parasternal plate, all with stiff setae of varying size. Tenth (anal) segment small, tri-cleft. Legs well developed, five-segmented, the claw elongate, slender and pigmented distally, with a seta on slightly wider basal part. Spiracles small, circular, that of thorax less than one-fourth as wide as labrum; the margin appearing as a series of contiguous semicircles in a narrow outer rim (fig. 9).

Described from ten larvae "attacking roots of cotton, Bulemezi, Uganda" (H. Hargreaves).

Family CERAMBYCIDAE.

Bixadus, Anthores. (Pl. vi, figs. 3, 4).

Mr. Hargreaves has sent me the larvae of two LAMIINAE, *Bixadus sierricola*, White (6 specimens, Toro, Uganda, Hargreaves) and of *Anthores leuconotus*, Pasc. (6

specimens, Zomba, Nyasaland); both species are stem-borers of coffee; the latter species is also recorded from Uganda, but not, apparently, as a coffee pest.

The larvae, which are very similar, come nearest to *Monochamus perplexus* in my key* to certain Indian larvae of the tribe MONOCHAMINI. In each the head is depressed, flattened above, elongate, rounded posteriorly; the posterior zone of pronotum (fig. 3) with a dense clothing of minute scales which shows a yellow sheen when seen from certain angles, and with some nude pitting; dorsal abdominal ampullae (fig. 4) with four transverse rows of contiguous tubercles, the latter microscopically asperate; anal lobe with three clefts, the two upper clefts nearly, but not quite in a transverse straight line; pleural tubercles with a pit at each extremity; thoracic spiracle a little more than half as wide as labrum.

The following distinguishing characters, although slight, are constant in the twelve specimens: In *Bixadus* the gula is smooth, its lateral margins quite well defined; hypostoma nearly smooth, with a smaller transverse depression behind anterior margin on each side of gula; the anterior zone of pronotum almost smooth, with some extremely shallow pitting. In *Anthores* the gula is not well defined laterally, usually with a few transverse striations; hypostoma usually transversely striate, the two anterior transverse depressions larger; anterior zone of pronotum finely irregular, distinctly pitted.

The largest larva of *Anthores* is 50 mm. in length and of *Bixadus*, 43 mm.; their stage of development is, however, not known.

Nitocris princeps, Jordan (Pl. vi, figs. 1, 2).

Larva: head thick, oval in cross section; antennal ring not intersected by frontal suture. Pronotum strongly asperate posteriorly and with a deep strongly oblique sulcus on each side. Abdominal ampullae with only one distinct transverse groove which is posterior. No caudal spines or other armature. The above characters are characteristic for the PHYTOECINI.

Head elongate, rather rapidly narrowed behind the middle; anterior margin, including whole of hypostoma, rather broadly castaneous. In addition to a larger ocellus near the antenna, there is a smaller secondary ocellus postero-ventral to the first. Pronotal plate (fig. 1) nearly quadrate, the anterior part testaceous brown, smooth and shining; the posterior part with regular dark brown asperities, graded in size to posterior margin, where they are small; this asperate zone extends medially to about the middle, but is much less deep laterally. Meso- and metanotum smooth, the first narrow, with two small soft approximate tubercles. Thoracic sterna smooth except for a narrow mat zone on the posterior two. First seven abdominal terga and sterna with densely and very finely asperate ampullae, those of intermediate segments smaller, that of 7th tergum larger than the others. The 9th tergum is somewhat expanded, transverse and inclined obliquely upwards. The caudal face with an obliquely truncate appearance, the lower half weakly convex, the upper half bearing the tri-cleft anus; the tergum of the anal segment projects very slightly and carries several stout brown setae. The spiracles are extremely narrow, almost linear. Length of larva about 30 mm.

Described from nine larvae taken from coffee stems, Kampala, Uganda (*H. Hargreaves*).

The shape of the caudal extremity is an unusual character.

Family ANTHRIBIDAE.

The characters of Anthribid larvae are defined by Böving and Craighead (1931) and by Gardner.† The former authors consider the group as a superfamily PLATYSTOMOIDEA (=ANTHRIBOIDEA) distinguished from the CURCULIONOIDEA by the presence of a hypopharyngeal sclerome and a molar structure on the mandible.

* Ind. For. Rec. 16 (3), 1931 p. 17.

† Ind. For. Rec. 16 (11), 1932.

Zygaenodes monstrosus, Pasc. (Pl. vi, figs. 12-14).

Larva (fig. 13) : Body rather strongly curved, stout, narrowing slightly towards head ; whitish, the head pale yellow ; setae numerous, fine, pale, some of them rather long. The greater part of the skin minutely asperate. Length about 6 mm.

Head almost circular in outline, frontal sutures not distinct. An ocellar pigment spot near ventral condyle of mandible is distinct on each side. Labrum transversely oval, about twice as wide as long, with three fine setae on each side and a pair of apical setae. Epipharynx with two apical and, on each side, four marginal setae ; nearer the middle is a quadrate group of four setae ; there are two pairs of circular sensory spots, one subapical, one near the middle ; laterally the skin with acute skin-points. Mandible with two sharp apical teeth and a third tooth near the middle. Maxillary mala (fig. 12) narrow ; with a strong lacinial spine well removed from the apex ; maxillary palp with three segments, the two basal transverse, the third elongate. Labial palps approximate, two-segmented. Hypopharyngeal sclerome (fig. 12) strongly sclerotised, transverse, anteriorly concave, projecting only slightly beyond hypopharyngeal bracon. Pronotal plate weak, not noticeably pigmented. Anterior abdominal terga with two folds, the anterior small and lenticular, the posterior larger and with a fine transverse depressed line across the middle. Pleural region moderately protuberant. Spiracles (fig. 14) circular-biforous with two small dorsal air-tubes ; all small, that of thorax, which is the largest, about one-fourth as wide as labrum. Legs (fig. 13) well developed, apparently with three soft segments arising from a basal cushion ; the apex obtuse, with several long setae.

Described from ten larvae from cotton seed (old bolls), Kampala, Uganda (*H. Hargreaves*).

Family CURCULIONIDAE.

Alcides leucogrammus, Er. (Pl. vi, figs. 10, 11).

Characters of subfamily value (ALCIDINAE) : Head subcircular in outline, not retracted into thorax, without a dark line (epicranial ridge) on each side posteriorly. Frontal sutures distinct. Antenna two-segmented, the basal segment a soft cushion, the apical segment small and conical. Labrum strongly transverse, the posterior margin with a distinct median extension under clypeus, with six setae on disc. Epipharynx with a pair of parallel rods which do not extend far into subclypeal zone ; anterior margin with six median setae (two of them dorsal) and with three flattened setae on each side ; between the rods are four stout setae and a pair of tripartite pores. Labial palps two-segmented, not widely separated ; labium with a very distinct, pigmented, trident-shaped sclerotisation. Mandible bidentate at the apex. Pronotum strongly transverse. Anterior abdominal terga with three transverse folds. Hypopleurum not subdivided. Spiracles biforous, with paired caudad air-tubes of moderate size, peritreme more or less circular.

These characters distinguish the group from many but not from all subfamilies of CURCULIONIDAE ; a character which will help to define the ALCIDINAE is that the tergum of the 9th abdominal segment is more developed than the sternum with the result that the 10th, or anal segment, is ventral in position and not terminal. I have examined eight species of *Alcides* larvae and all have a dark median line, posteriorly, on the frons.

Characters of specific value : Body stout, especially near middle, strongly curved ; length about 7 mm., width about 2.5 mm. Head smooth, not coarsely pitted. Of the two pairs of setae between the epipharyngeal rods, the posterior pair is more approximate and smaller than the anterior pair. Basal segment of labial palp (fig. 11) transverse, subequal in length to apical segment ; palps separated by slightly more than width of basal segment. Apical segment of maxillary palp stout, conical, hardly longer than wide. Anterior division (prescutum) of abdominal terga and

especially of the middle segments, large, evenly convex (not bilobed as in some species). Epipleura protuberant, subglobular. Ninth tergum a soft transverse lobe with slightly curved free posterior margin. Peritreme of thoracic spiracle oval; in the abdominal spiracles the paired air-tubes are not longer than the circular peritreme, in the thoracic spiracle much shorter. The body skin with short transverse rows of exceedingly minute points. Setae short or very short.

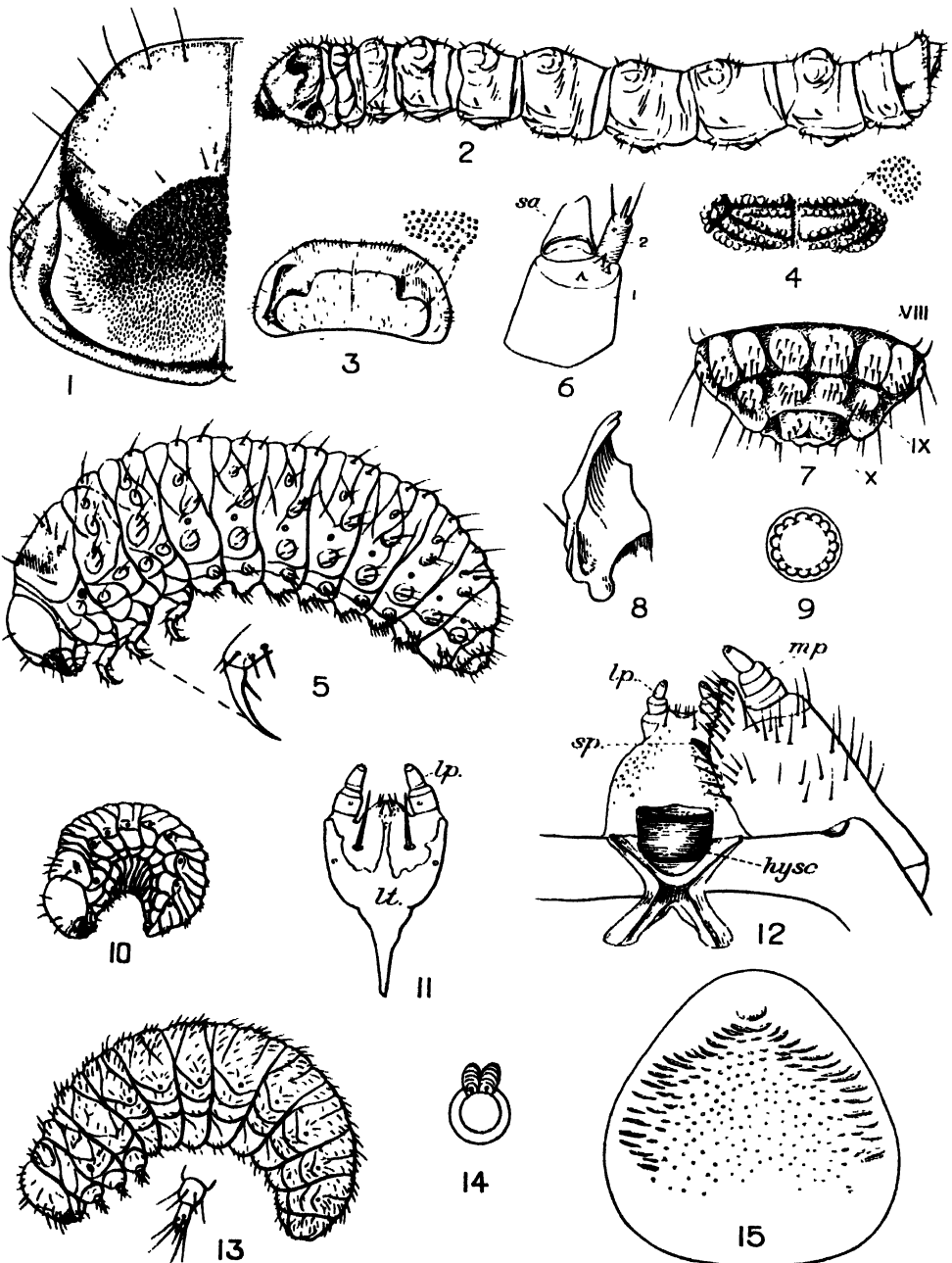
The larvae are discoloured, but the head is probably testaceous brown; there is one ocellus near each antenna, but secondary ocelli are not distinct, although perhaps evident in fresh specimens.

Described from two larvae ex stem gall of cultivated *Vigna* sp., Kampala, Uganda (*H. Hargreaves*).

Larvae of species of *Alcides* living in normal stems are rather slender, more or less cylindrical and weakly curved, and the skin is micro-asperate; the larva just described (from a gall) resembles the larvae of the Indian species *Alcides crassus*, which feeds in large seeds, in being stout and strongly curved.

EXPLANATION OF PLATE VI.

- Figs. 1, 2. *Nitocris princeps*, Jordan.
 1. Pronotum.
 2. Oblique lateral view of larva.
- „ 3, 4. *Bixadus sierricola*, White.
 3. Pronotum.
 4. Dorsal ampulla of 3rd abdominal segment.
- Figs. 5-9. *Syagrus calcaratus*, F.
 5. Lateral view of larva ; also a claw enlarged.
 6. Antenna ; *sa*, sensory appendage.
 7. Ventral view of posterior extremity.
 8. Mandible.
 9. Thoracic spiracle.
- Figs. 10-11. *Alcides leucogrammus*, Er.
 10. Lateral view.
 11. Labium : *lp*, labial palp ; *lt*, labial trident.
- Figs. 12-14. *Zygaenodes monstrosus*, Pasc.
 12. Ventral mouth-parts in dorsal view ; *hysc*, hypopharyngeal sclerome ;
lp, labial palp ; *mp*, maxillary palp ; *sp*, lacinial spine.
 13. Lateral view of larva ; also a leg shown enlarged.
 14. Spiracle.
- Fig. 15. *Atractocerus brevicornis*, L.
 Asperities on 9th abdominal segment.



John Bale Sene & J. A. Sene, 11¹ London

Coleopterous larvae from Uganda.

A VERY DESTRUCTIVE PEST OF STORED PRODUCTS IN SOUTH INDIA, *CORCYRA CEPHALONICA*, STAINT. (LEP.)

By P. N. KRISHNA AYYAR, B.A.

Madras Agricultural Department.

(PLATE VII.)

Introduction.

Among the diverse forms of insect life infesting stored agricultural products in South India those belonging to the Lepidoptera are by no means unimportant. Though no accurate estimates of the annual losses in value of grain, pulses, etc., due to their depredations are available in this country, it has to be admitted that the extent of the damage may occasionally be considerable. It is, therefore, unfortunate that these insects have not attracted sufficient attention at the hands of Economic Entomologists in this country; consequently very little information is available as to the exact identity of the species, their relative importance, or their life-histories. The present investigation was undertaken to make a detailed study of this problem in South India with a view to elucidating the points just raised.

The Caterpillar Pests of Stored Products.

As a result of a close study of these insects extending over a year and from available records of their occurrence, it has been found that the chief Lepidopterous insects concerned in South India are the fig moth, *Ephestia cautella*, Walk. (fig. 1);

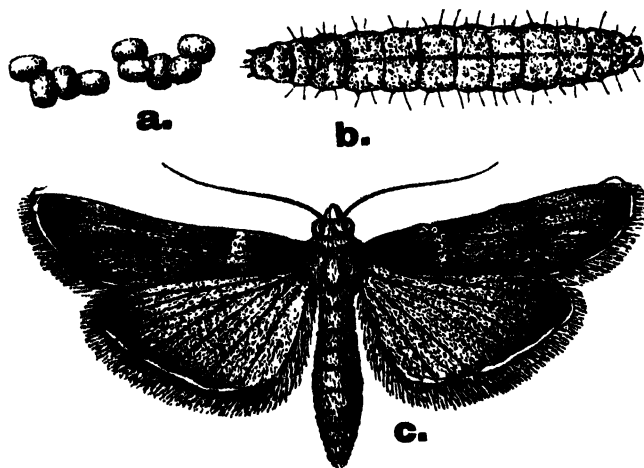


Fig. 1. *Ephestia cautella*, Walk., a, egg; b, larva; c, adult (after Chittenden and Smyth).

the Indian meal moth, *Plodia interpunctella*, Hb. (fig. 2); the rice moth, *Corcyra cephalonica*, Stn. (fig. 3, d, e); the common grain moth, *Sitotroga cerealella*, Ol.; and the potato-tuber moth, *Phthorimaea operculella*, Zell. Beyond some vague references to a few undetermined caterpillars in stored unhusked rice, the earliest records, such as the Indian Museum Notes,⁸ contain no specific report of any caterpillar pests of stored products, with the exception of *Sitotroga*. One of the earliest references to *Ephestia cautella* in this province was in the year 1907, when the insect was identified as such

by Lefroy. *E. cahiritella*, Ol., and *E. cautella* have been recorded by the same author^{9, 10} as feeding on rice and wheat flour in India. Later, in the year 1919, *E. cautella* was reported as occurring in stored groundnut pods in this province by Ramakrishna Ayyar.¹⁴ Fletcher⁴ makes mention of *Ephestia* as a pest but has figured another species namely *E. kuehniella*, Zell. (the Mediterranean flour moth), which the writer has not so far observed in South India, nor seen recorded as common in this province. In more recent years *E. cautella* has been recognised as damaging ground-nuts in Cocanada (in 1928). In the same year *Plodia* was recorded as infesting stored cashew-nuts in Mangalore. The first definite record of *Corcyra* in the province was in the year 1919, by Ramakrishna Ayyar.¹⁴ But the writer ventures to presume that the identity of these moths in the early references may have been to a certain extent confused and that previous records of any of these insects cannot be entirely relied on.

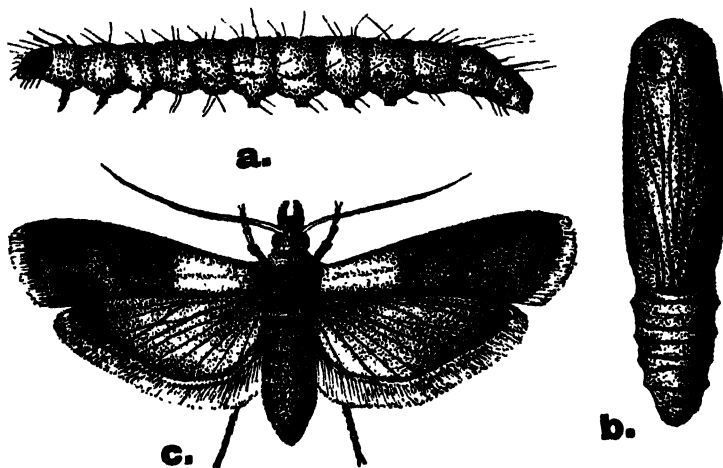


Fig. 2. *Plodia interpunctella*, Hb., a, larva; b, pupa; c, adult (after Flint).

Among these insects *Sitotroga* and *Phihorimaea* are sufficiently distinctive and cannot be confused with the other species. Since these are known to be restricted to specific materials, such as stored cereals and potatoes respectively, they may be regarded as comparatively of lesser importance than others that have a wider range of food materials. *Ephestia* and *Plodia* have been noted simply as occasional and general feeders. These have not been frequently observed in great abundance or as seriously destructive in South India, and therefore they may be said at present to be almost negligible. On the other hand, it has been recently observed that *Corcyra* has established itself as a serious enemy of stored products and may be authoritatively described as one of the most if not the most destructive pest in this province. Hence the problem of caterpillar damage to stored agricultural products reduces itself in South India mainly to *Corcyra* infestation.

The Image (fig. 3, d, e).

Corcyra cephalonica, Stn., belongs to the subfamily GALLERIINAE in the large family PYRALIDAE. Meyrick describes it as follows:—"Face with projecting tufts. Tongue rudimentary. Labial palpi short. Head ochreous whitish. Forewings greyish ochreous or light ochreous, along dorsum paler or whitish sprinkled; veins more or less streaked suffusedly dark fuscous, disc anteriorly sometimes wholly suffused dark fuscous."

It is comparatively a small moth, exhibiting considerable range of variation in size, but is generally larger than its associates *Ephestia* or *Plodia*. It is easily distinguished from *Plodia*, as the latter has the basal half of the forewing silvery white or grey with occasional minute dark spots and the outer portions reddish bronze with irregular dark bands. *Corcyra* is uniformly dark grey in colour with a few dark hair lines. The sexes are to a certain extent dissimilar in size, the females being ordinarily larger. The measurements across the expanded wings are : ♀, 14–23 mm., or rarely 24 mm., the average for 17 individuals being 19 mm. ; ♂, 14–18 mm., the average being 17 mm. for 17 individuals.

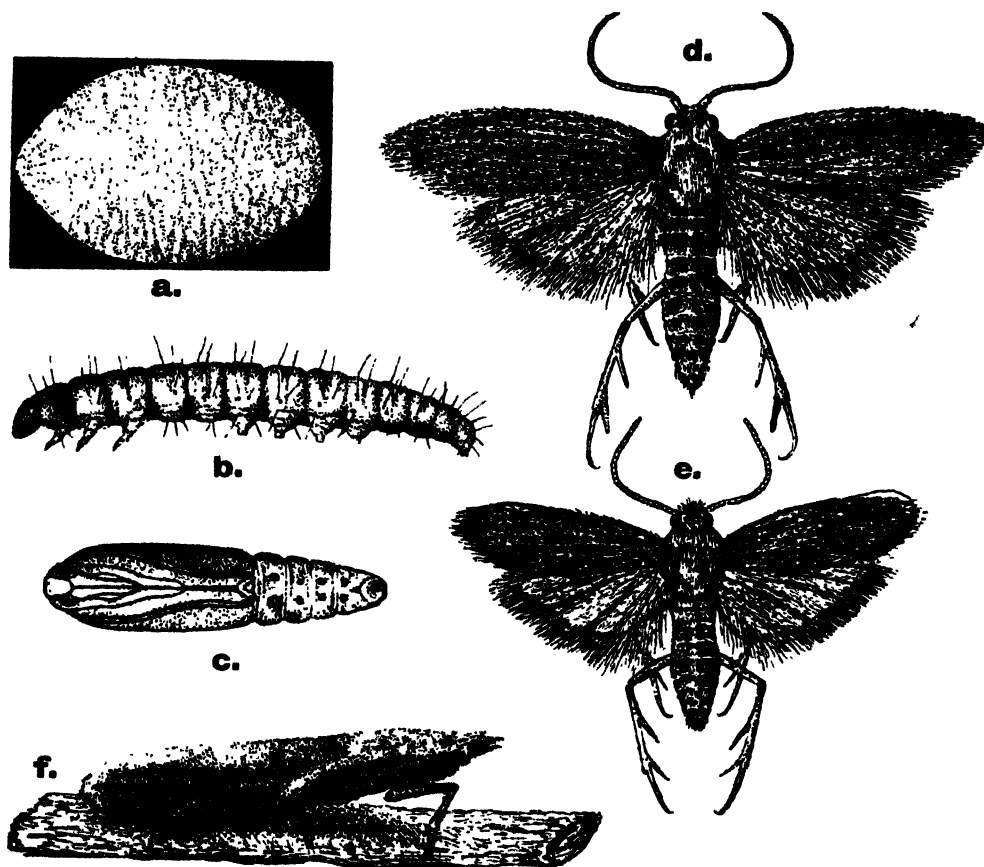


Fig. 3. *Corcyra cephalonica*, Stn., a, egg ; b, full-grown larva ; c, pupa ; d, adult ♀ ; e, adult ♂ ; f, resting attitude of ♀.

General Habits.

The moths are mainly nocturnal in habits being seldom seen active during the day. They seek dark corners, shaded walls, and heaps of food materials for shelter. Except when actually disturbed they are reluctant to fly, being rather sluggish. The flight itself is to a certain extent slow, clumsy, unsteady, and often takes a zigzag direction. Though not strong on the wing they are capable of sustaining their flight for some time but soon come to rest away from draughty places. Their presence in the resting places cannot be easily detected as their inconspicuous colour more or less blends with that of the background. Even in the proximate presence of strong light they take to flight only hesitantly, and it can be positively stated that they are not

attracted to any kind of light. Their resting attitude is very characteristic (fig. 3, f). The sexes can be easily distinguished at rest, mainly by the difference in the head region. In the female the head is elongate, with a nose-like projection due to the pointed elongate palps. In the males this projection is less conspicuous and generally blunt. The adults do not seem to need any kind of nourishment and are probably incapable of taking any.

Like *Plodia* and *Ephestia*, *Corcyra* is world-wide in its distribution, but as Meyrick¹¹ has stated, it is of doubtful origin. In South India very few authentic records are traceable. The first definite record of its occurrence in the province, to the best of the writer's knowledge, was in 1919 by Ramakrishna Ayyar in stored rice.⁴ It was recorded again in 1920 in stored cotton seeds, and more recently in groundnuts in Cocanada in 1928. Its occurrence in Coimbatore for several years past has been noted by the writer, and Fletcher⁵ referred to this species in 1917 as common in rice in India and Burma. Apart from these scattered references no thorough survey has been carried out, and hence its actual distribution is not accurately known, but it would appear that in South India the moth is fairly common and widespread.

Like its near Lepidopterous associates *Corcyra* is a general feeder with a remarkable catholicity of tastes. Although Chittenden² has christened it the "Rice moth," its range of food is extraordinarily wide, it having been noted in rice of various kinds, currants and other dried fruits, all forms of cocoa and chocolate, biscuits, sesame seeds, cotton seeds, maize, and bullrush millet, all in storage. It has been noted by the writer in this province as damaging stored materials such as cholam (*Sorghum*), Bengal gram, groundnut seed and cakes, wheat and wheat bran, rice and rice bran, cotton seeds, maize, red gram, green gram, tenai, ragi, cow-pea, and gingelly cakes. These have been enumerated in descending order according to the writer's estimate of severity of infestation and damage. It may be generally observed that under favourable conditions no material in storage is completely free from its attention.

Economic Status in South India.

Until comparatively recently this insect from all accounts was regarded as merely one of minor importance. This presumption probably accounts for the absence of any previous detailed study. In the writer's opinion *Corcyra* is by far the most abundant and destructive of the various Lepidopterous pests of stored products in South India. As its common name connotes, it probably was a rice pest originally, adapting itself later to other products.

In the course of his periodical examination of stores for demonstration of indoor pests to successive batches of students for the past several years, this insect has been noted by the writer to effect considerable damage to agricultural products, particularly to sorghum in storage in the Central Farm stores attached to the Agricultural College. But no previous infestation was so severe as the one noticed in the year 1932, when this insect was exceptionally abundant not only in cholam but also in Bengal gram, wheat and various other articles. Literally the moths were seen in thousands, resting in all sorts of places shaded from light, on walls, ceilings, sacks, tins, etc., and large heaps of stored cholam appeared to be reduced to a mass of webbing caterpillars in large clusters, dense silken white cocoons matted together with empty and unemerged pupae, frass, excreta, etc. (Plate vii). While on this aspect of the question it may be of interest to compare what Munro & Thomson¹² have recently recorded regarding the status and potentiality of this insect. They say that "*Corcyra* infestation in regard to stored cacao is as yet insignificant except in rare cases," but in the same breath rightly sound a note of warning that "this is an insect potentially dangerous." The latter part of the prophecy has soon proved to be only too true in regard to South India.

The little that is known of the biology of *Corcyra* is almost limited to the pioneer investigations of Chittenden,² who has provided a brief sketch of the insect, with a general outline of its life-cycle in the United States. Detailed description of the stages and several interesting points in the life-history, the number of generations a year, its fecundity, longevity, etc., have scarcely been touched upon. Since then little or nothing in the way of contributions to its biology has been added, so far as the writer could make out from available publications on the subject. It was deemed, therefore, desirable to make a thorough and detailed study of this dangerous pest with a view to elucidating the causes of its outbreaks and the best control methods under the storage conditions in vogue in South India.

Mating and Proportion of Sexes.

Generally copulation takes place soon after emergence, but is sometimes deferred for several hours. Newly emerged males when introduced into cages containing females begin their courtship immediately, darting hither and thither excitedly and shaking their wings, and frequently pair with the females in a few minutes. Pairing has been observed to last for an hour and a quarter in a few cases. The writer has not observed copulation being repeated, and probably the female pairs only once in her life. Oviposition does not take place immediately.

The number of females seems somewhat to exceed that of the males. In a lot of 54 individuals whose sexes were noted there were 34 females (63 per cent.) and 20 males (37 per cent.).

Longevity of mated and unmated Adults.

The length of the adult life of the moth has been ascertained to be comparatively short. It is probably subject to slight fluctuations, due to meteorological conditions. The longest period of life observed in the case of one individual was as much as 18 days during December 1932, but this figure was undoubtedly exceptional. Under the climatic conditions prevailing between January and June 1933 the average length of life for 12 individuals was as follows:—Mated female, 8.5 days; mated male, 9.5 days; unmated female, 8.25 days; unmated male, 10.5 days.

Oviposition.

In the laboratory eggs were normally laid at night, but occasionally during the day also. They are laid singly and not in groups, generally on any rough surface. In cages made of glass tubes the rough surface of the muslin plug is the most favourite place for depositing the eggs. Perhaps oviposition is stimulated by rough surfaces, but a small number of eggs may also be seen on the smooth glass sides. In stores, although the eggs are often placed on the food materials, they are mostly deposited indiscriminately on walls, bags and other uneven surfaces. In all cases the eggs are securely fastened to the surface by some sticky material.

The number of eggs laid by a single female is subject to great variation. Probably this capacity is dependent upon factors like suitability of the food, temperature, etc. Egg counts of a fairly large number of moths were obtained, and the maximum number laid by any single female has seldom exceeded 191; the minimum observed was 89, the average number for 25 individuals being about 156. Eggs are laid for about five days after copulation. No definite statement can be made in regard to the daily average on account of the total absence of any kind of regularity. The writer has noted that a small but variable proportion of the eggs is generally infertile. Whether this phenomenon bears any relation to the absence of repeated copulation cannot be stated without further evidence.

The Egg (fig. 3, a).

The egg is small, somewhat elliptical, with bluntly rounded ends, but is very variable in shape. It ranges in length from 0.5 to 0.65 mm., and the width is from 0.33 to 0.36 mm. When freshly laid the eggs are glistening and pearly white in colour. Examined under a lens or a microscope they are seen to have a rough, irregularly sculptured or shagreened surface, which is divided into small uneven areas. Many of the eggs possess a minute nipple-like protuberance at one end.

Although there is no striking change in colour before hatching, some slight successive variations in colour may be discernible. The outer shell, which is soft, becomes more hard and rigid before hatching. On the third day the bright colour gets slightly dimmed and assumes a slight touch of yellow, which develops into a dirty shade on the fourth day. Hatching usually takes place in the night or early morning hours. As the time of hatching approaches the eggs become slightly distorted in shape. In the process of hatching the darkish mandibles of the larva can be seen working rhythmically, and a ragged hole is bitten in the side of the egg through which the head is forced out. The larva takes nearly a quarter of an hour to work its way out (fig. 4, a).

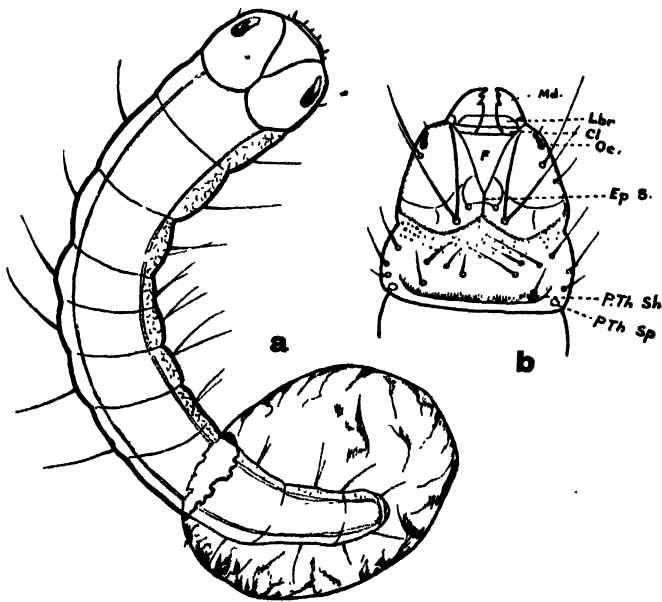


Fig. 4. *C. cephalonica*, Stn. : a, larva emerging from the egg-shell ; b, dorsal view of the head and prothoracic segment of the newly emerged larva showing mouth-parts, etc. *Md.*, mandible ; *Lbr.*, labrum ; *Cl.*, clypeus ; *Oc.*, ocellus ; *Ep. S.*, epicranial suture ; *F.*, frons ; *P. Th. Sh.*, prothoracic shield ; *P. Th. Sp.*, prothoracic spiracle.

The period of incubation does not show much variation, ranging from four to six days and averaging five days.

The early larval stages.

The newly hatched larva (fig. 4, a, b).—The first stage larvae is cream-white in colour and of uniform thickness. It measures in the extended state 1.0–1.25 mm. in length and 0.15–0.20 mm. in width. The head-capsule is yellowish white with a brownish margin and varies from 0.24 to 0.26 mm. in width ; the cervical shield is

not very distinct but demarcated as a light yellowish area measuring 0.22 to 0.24 mm. in breadth; epicranium light brown; frons pale brown; labrum light yellowish brown; mandibles brown with deep brown edges having three teeth; the region of the eye dark brown. The setae are whitish, the dorsal ones being as long as the width of the body. The anal plate is inconspicuous.

On emergence from the egg the larvae are active and able to wander about for long distances in search of food, beginning to feed almost immediately: even on a smooth glass slide they can crawl quickly. If disturbed they drop suspended on a silken thread. They are able to live without food for a day or two. When irritated they can curl themselves into a semicircle. On reaching food they settle down in silken shelters which they rapidly make by webbing small particles and frass. Occasionally they migrate to a new, more convenient place. They find some difficulty in feeding on whole hard grains, hence in the course of rearings they had to be supplied with broken grains. The instar lasts from five to six days, averaging six days. When they moult the cast skin is not traceable either at this stage or in subsequent stages, but it is not known whether it is devoured by the larvae themselves. The cast head-capsule, which is hard though minute, is the only evidence that ecdysis has been undergone.

Second stage larva.—After the first moult the general appearance of the larva does not undergo much change. The colour does alter slightly to dirty white owing to the feeding, but colour is of little value in distinguishing this or subsequent stages. The larva now measures 1.5–1.75 mm. in length and 0.25–0.35 mm. in width. This stage can be distinguished from the previous one by the deep yellowish-brown colour of the head-capsule, the arrangement of the setae is somewhat altered, and the thoracic shield is more pronounced. It takes, when touched, short leaps forward and is equally alert in moving backwards. This instar lasts from seven to nine days, averaging seven days.

Third stage larva.—Length 2.5–2.75 mm., width 0.4–0.45 mm. The head-capsule is a shade deeper in colour. The thoracic shield and the anal plate have become more distinct. The larvae feed under a more dense silken cylindrical covering, and it is difficult to follow individual development from this stage since they have to be disturbed from their galleries in the course of the search for the cast head-capsule. A few begin to display some slight irregularity in growth, but the great majority moulted within seven to eight days, averaging seven days.

Fourth stage larva.—Length 4.25–4.45 mm., width 0.5–0.6 mm. Head-shield with a dark border line, the mandibles darker and more prominent, the eyes conspicuously dark. Some larvae showed a wavy dirty streak along the dorsal median line of the abdomen, displaying the alimentary canal through the transparent cuticle. The larvae are generally less active than in the previous stages and seek hiding places more eagerly when exposed. They moulted within six to seven days, averaging six days.

Fifth stage larva.—From this stage the uneven growth of the larvae was more pronounced and consequently the range of variation in size is much wider.

Length 5.75–7.25 mm., width 0.8–1.25 mm. The general colour is dirty white. The silken gallery is thick and studded with numerous pellets of excreta and food grains. The habits are similar to those of the previous stage. Most of the larvae underwent ecdysis in seven to ten days, averaging eight days.

Sixth stage larva.—Length 8.0–9.0 mm., width 1.0–1.3 mm. The hairs are brownish in colour, and the tubercles from which they arise are not inconspicuous, the skin being somewhat rough or granulate. The larvae becomes more and more, fond of concealment and live in a denser covering. This stage ranged between four and five days, averaging four days.

Seventh stage larva.—Length 11.0–15.0 mm., width 1.1–1.4 mm. The mandibles and head-capsule are deeper in colour than in the stage preceding. The duration of this instar was the same as in the previous stage.

Eighth stage Larva : the full-grown Caterpillar (fig. 3, b).

Length 13.0–16.0 mm, width 1.2–2.0 mm. It is roughly cylindrical in shape, slightly tapering towards ends. The general colour is dirty white. The rounded head-capsule varies from 0.9 mm. to 1.1 mm in breadth and is reddish brown in colour. The thoracic shield is yellowish brown and about 1.3 mm. broad. The anal shield is dusky brown.

Head distinctly less broad than the thoracic shield, beneath which it can be partly retracted (fig. 5, a, b). Epicranium smooth and light brown. Antennae three-jointed. Mandibles prominent, with three distinct dark teeth. *Thoracic legs* (fig. 5, c) five-jointed, the tarsus darker in colour and terminating in a curved hook—the claw.

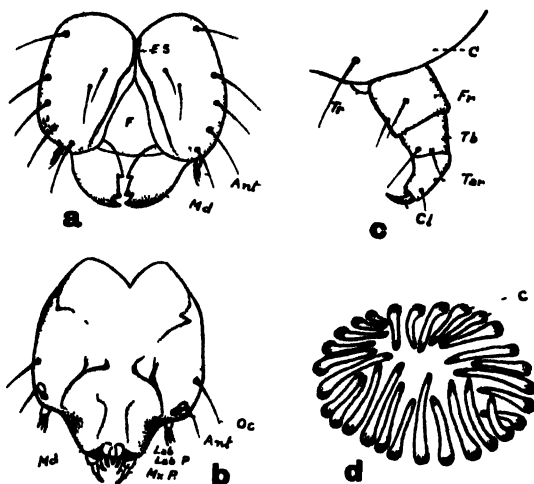


Fig. 5. *C. cephalonica*, Stn : (a) dorsal aspect of head of full-grown larva ; E. S., epicranial suture, F, frons, Ant, antenna, Md, mandible, (b) ventral aspect of head of full-grown larva, Ant, antenna, Mx P, maxillary palp, Lab, labium, Lab P, labial palp ; Md, mandible, Oc, ocellus (c) thoracic leg of full-grown larva, C, coxa ; Tr, trochanter ; Fr, femur, Tb, tibia, Tar, tarsus, Cl, claw, (d) ventral view of proleg of full-grown larva showing nature and arrangement of crochets (C).

Prolegs (fig. 5, d) about 0.8 mm. in length and creamy white in colour, those on abdominal segments 3 to 6 crowned with a complete circle of alternating short and long crochets, which are 28 in number. The anal prolegs are different and do not have a complete circle (fig. 6, c). *Spiracles* nine in number and more or less circular in form, clear and prominent, with a dark edge. The prothoracic and last abdominal spiracles larger than the rest (fig. 6, d, e). *Setae* with a brownish tinge, varying in length from 1.3 to 1.4 mm., and placed on minute brownish tubercles. Each segment has four, arranged approximately in four longitudinal rows along the body. The setae near the first and the eighth abdominal spiracles have at their bases an incomplete encircling dark ring.

The full-grown larva is at first fond of concealment and feeds enclosed in a silken web. Much variation in size was seen in larvae growing under identical conditions

of food, temperature, etc. When the larvae are ready to pupate a considerable proportion of them commence, as in *Ephestia*, to wander away in search of suitable situations for pupation, often migrating to the muslin coverings of the cages. A great majority of these larvae went into pupation in a period varying between four and five days, averaging about four days, but some took longer.

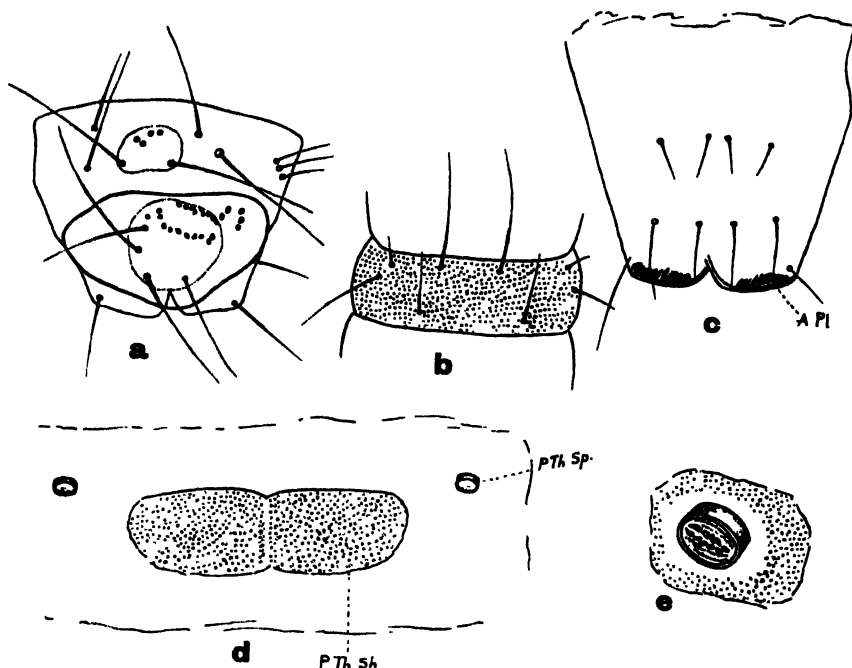


Fig. 6. *C. cephalonica*, Stn.: a, dorsal view of the tip of the abdomen showing anal plate; b, dorsal view of the third abdominal segment showing nature of the plate and distribution of setae; c, ventral view of the tip of the abdomen showing anal proleg (A. Pl.); d, prothoracic shield (P. Th. Sh.), prothoracic spiracle (P. Th. Sp.); e, an abdominal spiracle, showing its detailed structure.

Larval Instars and Developmental Periods.

Owing to unequal development the length of the larval life may vary both individually and probably to some extent with the season. A few individuals of the same parentage reared under similar conditions had a protracted larval life quite at variance with the average duration. But the great bulk of the brood bred in cholam between January and August 1933 approximated to the periods recorded in the preceding paragraphs. The entire larval period ranged between 46 and 56 days under the normal climatic conditions of the season, though some individuals had an abnormally long period rising to a maximum of 111 days. In size also they displayed great disparity in all stages of growth. The larvae are certainly larger than those of *Ephestia* and exhibit to some extent the same tendency to prepupal exodus. They are easily reared individually or collectively after the critical period of the first three instars, during which time some mortality may occur owing to different causes, particularly unsuitability of food. During these earlier stages they feed better on broken grains than on entire ones. The larval habit of living in concealment under dense silken galleries, coupled with the disappearance of the cast skin, renders the determination of instars difficult. The larvae had to be disturbed and their silken galleries torn off in order to search for the cast head-capsules. Careful examination

of these larval remains established the fact that there are eight larval instars, involving seven moults in both sexes. No satisfactory explanation for this deviation from the normal number of instars could be reached. The actual process of ecdysis was never witnessed.

Transference of the larvae at various stages from one food to another, such as from cholam to wheat, from wheat to rice, Bengal gram or maize, caused no appreciable change in them, as they continued to feed equally readily on the new substances. No case of cannibalism was noted by the writer, although known numbers of larvae were confined overnight in the same cage with or without food.

The Pupal Stage.

Cocoon.—The cocoon is more or less elongate and though thin in texture is stronger and more closely woven than those of other Lepidopterous store pests. The white silken structure is covered with small and large food grains, debris, excrement, etc. Not infrequently the cocoons are observed in clusters and matted together in sheets, and some of them display a slight, thinly woven, elliptical space at one end, probably as a provision for exit on emergence of the imago. After the cocoon is spun the larva becomes inactive and shrinks in size, this prepupal condition lasting for a day or at most two.

Pupa (fig. 3, c).—The pupa when mature is deep leathery brown in colour and measures 7.5–8.5 mm. in length and 1.45–2.0 mm. in width, the female being slightly larger than the male.

There was not much disparity in the length of the pupal stage; the maximum period observed was 14 days during February to August 1933, and the minimum 10 days, averaging about 12 days for 17 individuals.

Comparative Length of Life-Cycle in Different Food Materials.

Food materials	Date of introduction of larva	Date of emergence of first moth	Subsequent emergences	Days for first moth to emerge	Total life-cycle period
Rice	23.iii.33	16.v.33 (♀)	20.v.33 (3♂)	53 days	58
Tennai	"	5.v.33 (♂)	9.v.33 (♀)	42 "	47
Ragi	"	1.v.33 (♀)	6.v.33 (♀)	38 "	43
Maize	"	1.v.33 (♀)	5.v.33 (♀)	38 "	43
Bengal gram ...	"	14.v.33 (2♀)	21.v.33 (2♀)	52 "	57
Cow-pea	"	28.v.33 (♀)	1.vi.33 (♀)	66 "	71
Cotton seeds ...	28.vi.33	23.viii.33 (♂)	24.viii.33 (♀)	56 "	61
Groundnut pods	"	22.viii.33 (♀)	25.viii.33 (♂)	55 "	60
Rice flour	16.iv.33	8.vi.33 (♀)	27.vi.33 (♀)	53 "	58
✓ Cholam	23.i.33	23.iii.33 (♀)	26.iii.33 (♂)	57 "	62 ✓
✓ Wheat	16.ix.33	28.x.33 (♂)	8.xi.33 (♀)	42 "	47 ✓
Gingelly seeds ...	16.ix.33	15.xi.33 (♂)	—	60 "	65

There is considerable variation in the length of the life-cycle in different foods, as may be seen from the table above. This is not an occasional occurrence but appears to be a normal phenomenon, which is not easy of explanation, especially when it occurs in the same food under similar conditions. How far it is dependent upon the

moisture content of the food or other factors is a matter for further investigation. In order to ascertain the extent of variability in the length of the life-cycle larvae, mostly of the same parentage hatched on the same day, were placed in separate cages with different materials as food and the date of first emergence of the moth was recorded as shown in the table above.

From the table it will be seen that the larvae reared on maize and ragi developed more rapidly than the others, taking only 38 days, and the slowest growth occurred on cow-pea—66 days. The larva does not appear to thrive best in rice or rice flour, in which it takes 53 days to develop, and this fact renders its popular name of "rice moth" somewhat inappropriate. Further experiments are needed before the significance of these data can be properly appreciated; the factors that may have induced this disparity in duration are as yet too diverse and obscure to be determined even approximately, but it seems probable that the moisture content of the different kinds of food is a significant factor.

Seasonal Activity and Number of Annual Generations.

As might be anticipated from the variation in the larval development in any one brood, the number of generations of this moth in one year is subject to some irregularity, and the broods may overlap to a considerable extent. By taking the earliest lot of moths emerging from each brood nearly six generations are theoretically possible, taking the length of life-cycle in cholam, which is a little less than two months.

Commencing from a promiscuous emergence of moths in the month of November 1932, the life-cycle of the first generation was completed by the middle of January 1933. The eggs from the earliest emerging moths of this generation were utilised as the basis of the second generation, which was completed by the third week of March 1933. The third generation commenced with the earliest offspring of these moths and finished development during the third week of May 1933, when the first moths began to emerge. From these a fourth cycle was commenced and the first moths of this brood began to emerge by the middle of July; and a fifth generation started from these is fairly on the way to completion at the time of writing. The following figures indicate the approximate duration of each generation :—

16	17.xi.1932 to 15.i.1933	...	First generation	...	59 days
20	16.i.1933 to 22.iii.1933	...	Second "	...	65 "
	24.iii.1933 to 19.v.1933	...	Third "	...	56 "
	21.v.33 to 15.vii.1933	...	Fourth "	...	56 "
30	17.vii.1933 to middle of Sep-				
36	tember	...	Fifth "	...	? "

The mean duration for the four generations from November 1932 to July 1933 was thus 59 days. As the rearings progress and the season advances there arises a certain amount of confusion in the generations owing to the blending of different stages and generations brought about by uneven larval development. As the egg and pupal periods are approximately constant, being subject to only slight and negligible variations, the sole cause for the overlapping of the broods is the prolonged larval growth of certain individuals in any one generation. This factor may be slightly accentuated by the varying length of the life-cycle in different foodstuffs.

The data obtained from careful records maintained nearly for one year, 1932–1933, were found to be in conformity with the writer's experience of this insect for the last few years on the Coimbatore Central Farm. By keeping large quantities of infested material in the laboratory under observation and from experience in stores having heavy infestations, it was observed that twice in the year the moths were found to emerge in unusual abundance. Generally between June and August there was a large swarm of adults emerging, which continued in varying numbers till about November, when the population of adults reached its maximum. From February to

the end of May there was a spell of comparative inactivity, and the emergence of moths was then at its minimum. But it may be noted here that all the stages of the insect may be met with at all seasons in sufficiently large numbers.

Probable Causes of Heavy Infestation.

Like its near allies *Corcyra* is essentially an indoor pest and a normal inhabitant of stores in South India. From its sluggish habits and erratic flight it may be inferred that it is incapable of spreading much by its own efforts. Hence the main agency of its dissemination is by the distribution of infested food materials.

The conditions prevailing in some stores in South India provide a favourable breeding-ground, ensuring a good and continuous supply of food. Cholam and other materials are in storage for a long period on most farms, in stores and elsewhere throughout the year and serve as a perennial reservoir of infestation until the new season's crop is brought in. Large accumulations of stored foods, little disturbance, scanty ventilation and lack of strong light, are all factors extremely favourable for the perpetuation and increase of this pest. From general observations it may be suggested that there is good reason to believe that the moisture content of the food materials may have a direct influence on the development of the insect, so that dry storing may produce some tangible effect in reducing infestation. But the subject of epidemiology requires more elaborate and carefully planned study.

Control Measures.

It is not unjustifiable to state that neither the losses caused annually by the ravages of store insects, nor the value of efficient preventive or remedial measures for minimising their damage, have been appreciated by the agriculturists of this province, and some of the commonest methods for combating these pests have not as yet gained sufficient popularity. Since many of the measures advocated against *Corcyra* are also effective against the majority of other store pests, it is deemed advisable to recount as briefly as possible the more important methods of prevention and control.

Some of the indirect methods of control, such as cleanliness in stores, quick handling, and periodical exposure to the sun's rays of articles in storage, are not to be despised as too commonplace. Much infestation could be prevented, or at least reduced, by timely clearing of the previous season's crop and proper cleaning and disinfection of the store-rooms some time prior to the introduction of the new season's produce. The clearing operation should, of course, be thorough and should cover the floors, walls, ceilings and all kinds of receptacles.

Trapping.—As it had been reported by Myers¹³ that other moth pests of stored materials are attracted by tea devoid of sugar and milk, a few trials with tea were made for testing the response of *Corcyra*. Liquid tea was left exposed in shallow dishes overnight in large containers where moths were emerging from infested cholam. A control was kept by merely exposing water under similar conditions. Only six moths were found to be caught in the tea and three in the control, so that it was inferred that tea has little attraction for *Corcyra*.

Fumigation.—In places where the insect has become established the best method of eradication is by fumigation. Among the more widely used fumigants are carbon bisulphide, hydrocyanic acid gas, carbon tetrachloride, ethylene chloride, and ethylene oxide. Carbon bisulphide and hydrocyanic acid are in very common use for treating infested materials in South India. Both diffuse rapidly and penetrate heaped materials in store. In the writer's opinion these stand pre-eminent among the fumigants, although hydrocyanic acid possesses the higher lethal effect, whether evolved by the liquid method or by exposing calcium cyanide. Owing to its non-inflammability carbon tetrachloride in combination with more powerful compounds, particularly ethylene dichloride in the proportion of 1 : 3 (14 lb. to 1,000 c. ft.), is being used extensively in other countries. Ethylene oxide, a recently developed fumigant, shows indication of a promising future. It is reported to be effective

against insects when mixed with carbon dioxide (proportion 2 lb. to 1,000 c. ft.), and the fact that it is non-explosive and non-inflammable gives it a decided advantage over other substances.

The choice of a fumigant will depend on the reaction and resistance of different insects to the several poisonous gases ; moreover in one species the different stages exhibit great variation in resistance to the same fumigant. Hence the question of the determination of the degree of resistance of various stages of insects is an important branch of study, without a knowledge of which no control measure can be deemed fully effective. Many of these common fumigants are known to be effective against all stages of insects, except perhaps the egg-stage. Considerable work in this direction has been done by Cotton,⁸ but his experiments were directed against all stages except eggs, which are the most difficult and most resistant stage to deal with. Trials with carbon bisulphide and hydrocyanic acid gas have been reported to have partly failed against eggs. Hence it was anticipated that data of some economic value might be obtained by experiments on the resistance of eggs, and the following preliminary tests were made on a small scale, as facilities for extensive experiments were inadequate.

Fumigant	Concentration	No. of eggs treated	Number hatched	Per cent. mortality
Carbon bisulphide ...	4 lb. per 1,000 c. ft. ...	36	8	78
" " ...	8 lb. " ...	36	3	92
" " ...	12 lb. " ...	36	2	95
Control ...	... ..	36	28	—
Calcium cyanide dust ...	1½ lb. per 1,000 c. ft. ...	36	14	61
" " ...	3 lb. " ...	36	8	78
" " ...	4½ " ...	36	7	80
Control ...	... ..	36	29	—
Ethylene dichloride 3 parts plus 1 part carbon tetrachloride	5 lb. per 1,000 c. ft. ...	36	16	55
	10 lb. " ...	36	10	72
	15 lb. " ...	36	8	78
Control ...	... ..	36	30	—
Ethylene oxide ...	2 lb. per 1,000 c. ft. ...	36	10	72
" " ...	3 lb. " ...	36	9	75
" " ...	4 lb. " ...	36	9	75
Control ...	... ..	36	35	—

A known number of freshly laid eggs of *Corcyra* was placed in perforated pill-boxes and also in small glass tubes, and these were deposited in large jars of known capacity. A calculated quantity of the fumigant or mixture of fumigants was introduced into each of these jars in different degrees of concentration, and these were kept tightly closed. A sufficient number of eggs in pill-boxes was kept as control in

each case, and after the lapse of about 24 hours the jars were opened and the pill-boxes and tubes exposed and aerated, and the number of treated eggs that hatched was recorded as an index to the efficacy of the fumigant. The table on p. 167 presents the results obtained.

Apart from the inherent defects of the experiments, the results cannot be taken as conclusive without repeated and extensive tests, particularly because of individual variations and the undetermined proportion of infertile eggs. From the above experiments it might be supposed that all eggs could be destroyed by treating the material with any of these fumigants in rather strong doses. But it must be remembered that the eggs were isolated and kept separately in the poisonous gases in small containers; whereas in large stores the scattered eggs are promiscuously mixed with heaps of food materials, where it is more difficult for the gas to reach them, and its lethal effects are likely to be considerably reduced. However, it may broadly be stated that of the fumigants tested carbon bisulphide has given the most satisfactory results.

Radio Methods.—Recently radio methods have been effectively employed in other countries to exterminate eggs and larvae which may be concealed within the material, as also the adults. High-power short-wave radiations are reported to induce lethal temperatures in animal life in stored materials, so that all stages are said to be destroyed with expedition and ease. Should facilities be available for this measure, it promises to be one of the easiest methods of controlling store pests and might eventually displace all others.

Parasites.—Two parasites, a small Braconid, *Habrobracon hebetor*, Say, and a Chalcid, *Antrocephalus mahensis*, Masi, have been encountered in numbers in store-houses and have also been obtained from *Corcyra* infesting cholam in the laboratory. Both occur in fairly large numbers, but the Braconid is comparatively less numerous. The Chalcid has been noted to emerge from the cocoon of the host at about the time of the emergence of the moth. It seems to exercise ordinarily a considerable degree of control on the moth, but data regarding its incidence and life-history are at present insufficient to permit of a reliable estimate as to its efficiency. This parasite does not seem to have been recorded previously from *Corcyra*.

Acknowledgments.

It only remains for the writer to acknowledge the generous help that has been received from Dr. T. V. Ramakrishna Ayyar in several directions in the course of this investigation, particularly for affording to the fullest extent the benefit of his wide experience. The writer also wishes to express his gratitude to Rao Bahadur M.R.Ry., C. Tadulingam Avl., F.L.S., Principal of the Agricultural College, for the facilities afforded in the study.

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THE BIONOMICS OF THE BULB-SCALE MITE, *TARSONEMUS APPROXIMATUS*, BANKS, VAR. *NARCISSI*, EWING.

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(PLATES VIII & IX.)

Introduction.

In January 1932 the writer received for examination a sample of narcissus bulbs, variety *Diadem*. The bulbs, which had been grown in Abingdon, England, for a number of years, were submitted on account of their persistently unsatisfactory growth. It was found that they were heavily infested by a species of *Tarsonemid* mite, which was present in sufficient numbers to account adequately for the unhealthy condition of the bulbs. No record could be found relating to the occurrence of such an infestation actually in Europe; the condition was, however, already known in the U.S.A. Ewing⁴ in 1929 described a new *Tarsonemid* occurring in narcissus, which he named *Tarsonemus approximatus*, Banks, var. *narcissi*, Ewing. The mite was named from material obtained in narcissus bulbs from the Pacific coast, which bulbs it appears had been imported from Holland. Doucette⁵ in the same year, 1929, published a short account of the activities of the mite with which he had become familiar in both Philadelphia and California as early as 1925, in these cases also in bulbs of Dutch origin. No other reference to the mite could be found in literature, although it is perhaps hardly necessary to state that allied species are known to be highly injurious to plants, e.g., *Tarsonemus tepidariorum* on ferns (Cameron¹), *T. fragariae* and *T. pallidus* on strawberry (Massee⁷), and *T. essigi* on blackberry, etc. (Essig³).

A number of the mites taken from the *Diadem* bulbs were sent to Ewing, who stated that in his opinion they were identical with the species found by him in America. This opinion was given with some reservation on account of the limited quantity of material sent for examination, but was confirmed by both Oudemans in Holland and Massee in England, who had meanwhile examined more abundant but otherwise similar material. More recently Massee⁸ has published a brief account of the discovery of the mite in England, has recapitulated Ewing's original description, and has added figures by Oudemans and himself which materially assist in identifying the mite.

Within a few months of the mite first being discovered in this country at Abingdon, it was also found at Penzance, Cornwall; Bromham, Wilts; Slough and Taplow, Bucks; in fact it was clearly of widespread occurrence. Further, in June 1933 the writer observed it to be not uncommon in Holland, and infested stocks have also been found in Guernsey. Varieties of narcissus in which the mite was seen in 1932 included *Soleil d'Or*, *Argent*, *Sir Watkin*, *Diadem*, *Golden Spur*, *Emperor*, *Victoria*, *King Alfred* and *Dante*. Latterly many other varieties, particularly those of general commercial use, have been found to be infested in widely separated localities. From the frequency with which the mite occurs it can only be inferred that its abundance is no very new phenomenon, but that it has in the past, by some strange mischance, been overlooked.*

It was obvious from the outset that an investigation was desirable as to the importance of the mite as a pest, and a preliminary account of its activities has

* See Appendix, p. 185.

already been published by the writer.⁶ The biology has now been studied in some detail, and indisputably the mite constitutes a pest of no little importance. It is also clear that the nature of the attack is such that in practice infestations are quite frequently overlooked, the injury erroneously being attributed to other causes. Initially it must be fully appreciated that the mite is entirely distinct from the larger and well-known Bulb Mite, *Rhizoglyphus echinopus*, Fum. & Robin, an account of whose biology was published in 1927 (Hodson).

Description.

Adult.—The mite is entirely typical of the family CARSONEMIDAE, which may be separated easily from the TYROGLYPHIDAE and in fact from all other Acarina by the presence, in the adult female, of a pair of prominent clavate organs situated between the first and second pairs of legs.

The mites are soft-bodied and of minute size, being only 1/120th of an inch in length. The sexes are markedly dissimilar in that in the male (Plate viii, fig. 1) the hind legs constitute strong clasping organs, whilst in the female (Plate viii, fig. 2) they are feeble and terminate in elongate bristles.

A detailed technical description of the mite under consideration is not included here for this has been adequately made in publications by both Ewing⁴ and Massee.⁸

Larva.—The larval stage, of which there is but one, is hexapod. When fully mature the larva is quite as large as the adult. It is pale or colourless, glistening, and more or less translucent. Until the immediately pre-adult stage, which is in the nature of a resting period, the larvae, when disturbed, are capable of comparatively rapid movement.

Egg.—The eggs, which are relatively large, are laid singly. In shape they are oval and in colour pearly white. There is no apparent change in colour between the time of laying and of the emergence of the larva. The surface is faintly but distinctly granulated.

Symptoms of Attack.

In the dormant bulb.

Bulbs heavily infested with the mites are recognisable with a tolerable degree of certainty on superficial examination, both at the time of lifting and during storage. In appearance they are abnormally dry and in addition are light in weight. It is typical to find that the dried outer scales adhere very tightly to the bulb, some are incomplete, and they are more numerous than is usually the case. In addition to the dry appearance the bulbs are frequently quite definitely below the size to be expected and are somewhat soft.

If a dormant mite-infested bulb be cut through with a sharp knife in a horizontal plane, at a point about $\frac{1}{4}$ inch below the apex (Plate ix, fig. 1), diagnosis can be made with certainty. Small patches of brown tissue will be disclosed on the cut surfaces, the patches occurring most frequently at angular points in the scales. The scales should be carefully parted, when streaks of brown or yellow tissue will be disclosed. The streaks are associated with a greater or lesser amount of callus formation, and run longitudinally down the scale-walls from the apex to the extreme base of the individual scales (Plate ix, fig. 2).

Examination with a binocular microscope or with a powerful lens will disclose numbers of the mites, in all stages of development, congregated upon the discoloured areas. This examination must be made immediately upon opening up the bulb, for the mites rapidly seek cover when only eggs, dead bodies, and cast skins will remain visible. The attack, in all but very advanced cases, is confined entirely to the outer cuticular region of the individual scales. The ring-like effect, produced

by diseased tissue, so typical of infestation by bulb eelworm, *Anguillulina dipsaci*, is not usual in attacks by bulb scale mite. The mites, except sometimes in the immediate vicinity of the bulb neck, invariably work in longitudinal strips between the scales and not round the individual scale. In the case of advanced attack, and more particularly in bulbs which have been for some time in store, the loss of water within the bulb is very appreciable. As a direct result of this loss the scales shrink slightly, air-pockets thickly populated with mites are formed, and the whole bulb becomes flaccid. Normally an attack is never so severe as actually to kill a bulb, although the weakened condition is likely to admit other and more rapidly destructive organisms.

In the forced bulb.

It is in the infested bulb which is used for forcing purposes that the most far-reaching and obvious damage is to be observed. Immediately upon a bulb being subjected to abnormally high temperatures a rapid increase in the mite population commences, and in a very short time epidemic proportions are arrived at. The mites congregate in numbers, principally in the vicinity of the bulb neck. Under these conditions they are plainly visible to the naked eye as minute specks, particularly on the basal regions of the young leaves. Later on as the flower-buds protrude these also become covered. During the earlier stages of the attack the mites shun daylight, in a manner typical of the majority of Tarsonemids, but as they increase in numbers this habit is at least in part abandoned. Eventually they may be found, even during the day, freely distributed over the foliage, and eggs are often deposited many inches above ground-level on both inner and outer surfaces of the leaves. In passing, it may be noted that eggs laid in such exposed sites rarely hatch. In numerous infestations observed in commercial forcing-houses, and therefore presumably of usual intensity, the abnormally bright green coloration of the foliage has been an obvious feature of attack. This departure from normal colouring is largely due to the loss of "bloom" which is commonly present upon the foliage of many varieties of narcissus, notably upon that of most daffodils. The foliage of these, in the case of heavy infestation, assumes a glaucous appearance, more typical of certain of the Polyanthus type of narcissus, such as Soleil d'Or. Associated with this general departure from normal coloration of the foliage, which may be more or less pronounced, is the occurrence of definite flecks and streaks of yellowish colour. These latter discolorations are in fact the actual feeding marks of the mites and often are almost if not quite indistinguishable from "Yellow stripe," a little understood complaint of narcissus which is a form of mosaic infection (McWhorter⁹, Hodson⁶).

In the case of mite infection of forced bulbs it is typical to find lunate areas abnormally light in colour situated about $\frac{1}{2}$ inch below the tip of at least the two innermost pairs of leaves. The marks are made by those mites which congregate at these points almost immediately upon the bulbs first being subjected to artificial heat. As may be expected, forced bulbs infested to the degree suggested above tend to lose vigour at an early date, as is evinced by the premature and general yellowing of the foliage.

Let us turn now to a consideration of the effect upon the flower itself. As previously stated, mites congregate upon the buds at about the time at which these are extruded from the bulb neck. This stage in the growth of the plant is that at which it is normally brought into the forcing house, and the ultimate effect of the congregation upon the flower-bud is a direct indication of the quantity of mites present. In extreme cases bud and flower stem are killed *in situ* and wither up. A less severe infestation kills the bud, but the stem, bearing a blind bud, continues to extend. This is perhaps the commonest type of attack. The symptoms are well known to all commercial forcers, who in the past have often attributed the death of flower-buds either to faulty watering or to the premature application of heat.

Both these factors most certainly can produce such results, but in the majority of cases examined it has been found that in actual fact mite injury was the deciding factor. In attacks of lesser severity the flower-buds may not be killed but, weak, imperfect, and inferior flowers result.

*Bulbs in the field.**

Symptoms far less extreme than those described above are usual in the field, except in abnormally warm dry weather. Despite this the cumulative effect upon the bulb of mite infestation is extremely serious. It must be appreciated that in a forced bulb, subjected to artificial warmth, mites are stimulated to inordinately rapid increase before their normal season and at a time when the bulb is making soft and rapid growth. Under outdoor conditions this is not so. Narcissi, it need hardly be stated, are early spring flowers, and vigorous growth takes place whilst temperatures are still too low to induce rapid increase in the mite population resident within the bulbs. During the winter this population, at least in bulbs remaining in the ground, is relatively small. Hence it is usual for infested bulbs to produce comparatively normal growth up to and during the time of flowering, except in the few late varieties. Nevertheless, the mites are not entirely inactive during this time. Feeding marks, visible as yellow streaks and blotches often minutely speckled with brown, become apparent upon the lower regions of both foliage and flower stems by the time that the former is some 6 to 8 inches high. In April and early May when both day and night temperatures rise the population increases with remarkable rapidity, feeding marks become more apparent, and mites wander freely all over the foliage. These activities bring about a very premature wilting and death of the leaves which reflects seriously upon the food storage process within the bulb. This ultimately leads in turn to a definite reduction both in size and stamina of the bulb.

As the foliage dies back the mites wander along it and so cross to adjacent bulbs. By early or mid-June they have all withdrawn once more between the bulb-scales. Thence onwards they gradually work their way down, wherever space is available, meanwhile feeding and ovipositing on the scale-walls, thereby still further reducing the vitality of the bulbs. The sum total of these activities extending over one or more years brings about a definite diminution in the size of the bulb, sometimes to the extent of reducing it to as little as half that normal to the variety. Associated with the dwindling in size is the production of poor unhealthy top-growth which tends to die off prematurely.

Stocks of bulbs exhibiting the symptoms described above are by no means uncommon on commercial plantations and by growers are often called "degenerate." This degeneration is sometimes ascribed to such causes as unsuitable soil conditions or to over-rapid increase of stocks by too frequent division. In several cases which it has been possible to investigate, it has been found that bulb-scale mite has been present in such numbers that the bulbs could not possibly be expected to behave otherwise.

Technique for Study of Life-history.

Pressure of other duties has been such that a really comprehensive study of the life-history of the mite has not been possible. At the same time such information as has been gleaned is not without use and is therefore recorded here.

The concealed nature of the mites' usual habitat precludes prolonged observation under strictly natural conditions, and a technique had to be evolved which permitted of observations at will. Initially attempts were made to breed the mites upon

* Since this account was written cases have been seen in which mite infestation has been so high in February as to inhibit entirely the growth of leaves, a distorted flower stem only being extruded from the bulbs.

portions of fleshy bulb-scale, isolated upon damp filter-paper, in glass cells. This method proved useless, for there was a tendency for moulds to develop within a few days, the portions of bulbs soon became discoloured and deteriorated, and the mites showed no inclination to settle down. The use of small glass cells, composed of ring and cover-slip applied either to the sides of skinned bulbs or to foliage was also abandoned. These cells proved unsatisfactory for observation purposes, principally on account of unavoidable condensation of water, which both obscured the view and trapped wandering mites.

The method finally employed was as follows: Very small dormant bulbs were selected, all outer skins were removed, and the bulbs were placed singly upon very slightly damped filter-paper in small solid watch-glasses. The glasses were covered by thin sheets of glass and sealed with vaseline. On each bulb a single adult female was released, and except when actually under observation the cells were kept in a dark cupboard. Given these conditions the mites bred freely for some considerable time. As already pointed out such observations as were made are very incomplete. They relate entirely to activities observed from February to April in a laboratory, heated only by day, in which the temperature fluctuated violently and frequently between say 40°F. and 65°F.

Parthenogenesis.

The original female mites were obtained from a bulb in February, a time at which males are very scarce. In fact not one male could be found in that particular bulb. Nevertheless the females nearly all oviposited and the eggs were fertile, which suggested that, at least in the winter months, parthenogenesis might occur. Meanwhile evidence that this is so was obtained in two of the eight cells employed. In six of the cells the mite colonies came to an untimely end at an early stage, principally on account of the profuse development of moulds. In the remaining two, strong colonies were built up without males appearing until at least the third generation.

Duration of the Life-cycle.

The females when isolated were naturally of unknown age and the number of eggs laid by each ranged from five to twenty-eight. The eggs were laid singly and the individual which laid twenty-eight lived for thirty days after being isolated. Eleven days was the normal duration of the egg-stage as observed, the shortest time being eight and the longest sixteen days. No larvae were re-isolated, so exact observations as to the duration of the active larval period are not available. The first larva became fully fed and quiescent sixteen days after the first egg hatched and was followed very shortly by others. This suggests an active larval life of around fifteen days. The quiescent stage in several observed individuals lasted three days. This gives a cycle from egg to adult of approximately seven weeks.

It must be fully appreciated that these observations, in themselves very incomplete, relate only to the length of cycle under one set of conditions. The rapidity with which the mites increase in numbers at higher temperatures indicates that the cycle may be very materially shortened, quite possibly it is reduced to a matter of ten or twelve days. Conversely, at soil temperature in winter and early spring it may extend to three or more months. On these and other points further information will be sought as time permits.

Seasonal Biology.

A study of the mite population of infested bulbs over a period of twelve months brings to light several facts of interest. The number of mites present fluctuates

considerably from season to season and the focus of attack also varies. At no time are eggs and immature forms entirely absent, feeding is apparently never at a complete standstill, hence there is no respite for the bulb.

If a newly lifted bulb be examined in, say, the latter part of July it is found that the great majority of the mites are congregated within the vicinity of the bulb neck, in other words the focus of attack is upon the living tissue situated within about half an inch of the extreme apex of the bulb. At this time the bulb, if in reasonable vigour, is so turgid and solid that much deeper penetration by the mites is physically impossible, for it must be remembered that they live between and not within the scales.

During the months of August and September, and in fact until replanted, narcissus bulbs gradually lose water. As a result some shrinkage takes place and minute or even considerable air-spaces appear between the fleshy scales. These spaces are most apparent in those angles present in all but the most symmetrical of bulbs. Down these crevices the mites gradually work, almost always in narrow vertical strips, and their activities produce the quite definite streaks upon the scale walls. The streaks, as previously mentioned, extend eventually from the apex to the extreme base of the individual scales. In colour they are at first definitely yellow, later becoming brown as the injured tissues crack, finally callusing to a greater or lesser extent. Throughout this period the mite population remains comparatively small and by October or November consists very largely of adult females. Nymphs and eggs remain present sparingly but males only constitute about 5 per cent. of the adult population. During the winter, at which time the bulbs are normally in the soil, the mites are extremely sluggish but tend always to work further and further towards the basal regions. As soon as root action recommences in the bulb the mite population becomes reduced to a bare minimum directly as a result of this action. With considerable rapidity the bulbs regain their lost solidity, the scales swell and large numbers of the mites are crushed flat between them, often only those inhabiting the neck region escaping disaster. In comparatively vigorous bulbs and particularly in those of symmetrical form this destruction of mites is very complete. It is not unusual to find that in such bulbs only a few dozen living mites are present in February, although dead and crushed bodies may be found in hundreds. It was at first thought that the wholesale deaths taking place in January and February might be due to some other cause and that the crushing of the bodies occurred subsequently. It has, however, been ascertained that extensive deaths do not occur in bulbs which are kept out of the ground at this time and so do not become turgid. Further, in definitely asymmetrical bulbs and in bulbs injured also by other organisms no such deaths take place even if the bulbs be in the soil. Bulbs in these categories may therefore be expected to carry over a much larger mite population into the spring. It has also been ascertained that bulbs left in the ground for two or more consecutive seasons suffer more severely than similarly infested bulbs which have been lifted and replanted. This is explainable on the score that bulbs left in the ground remain persistently more solid than those lifted and held in store for some weeks or even months. Hence in the former many of the mites remain always in the neck regions, for they are less easily able to penetrate deeply between the scales, and so considerable numbers persist comparatively unchecked throughout the winter and spring months.

In February, or earlier in the South-Western districts, as the foliage elongates, a concentration of the mites takes place upon the white fleshy bases of leaves and flower-stems. Here extensive feeding takes place, and thereby is produced the typical streaking and blotching which becomes visible as the foliage grows taller. Gradually the attack spreads over the whole of the subterranean portions of leaves and stems; eggs are produced in profusion in March and April, but at this season the mites show no tendency to populate the exposed and green portions of the plant.

Meanwhile the percentage of males produced rises rapidly until, by May, the sexes are present in about equal numbers.

Wet and cold spells of weather keep the mites within bounds, but with the occurrence of warm dry periods in May and early June the numbers become prodigious. In fact the favoured breeding-grounds may become over-populated when ovipositing females travel up the leaves at night, some but not all retiring to cover by day. Numerous eggs are laid frequently some inches above soil-level, where when sufficiently numerous they are clearly visible as small dusty patches on the leaves.

It is in early June that migration from bulb to bulb takes place freely. Normally the mites do not leave the plant and in fact appear only able to exist for a very short time when removed from the host-plant. Migration takes place by way of the foliage, over which at this time both males and females wander freely, particularly in warm dull weather. As the foliage matures and commences to flag, a more or less solid mat is formed, when distribution of the mites over a whole bed becomes an easy matter. Immediately the foliage actually withers, the mites retire once more within the necks of the bulbs, where breeding continues on the upper portions of the fleshy scales. This brings us once more to the point at which the account of the seasonal activities commenced.

The foregoing indicates that in the field destruction of the flower-bud is unlikely. The comparatively small number of mites present in early spring are quite unable, owing to the prevailing low temperature, to increase with sufficient rapidity to destroy, or even materially to injure, the rapid growing and early maturing flower-bud. In the forced bulb the reverse often obtains. There the early application of heat permits of such rapid increase at an early stage in the growth of the plant that partial or complete destruction of the bloom becomes well nigh inevitable.

Control Measures.

It would appear that bulb-scale mite has become a comparatively severe pest rather on account of lack of recognition than on the score of there being any real difficulty in devising or adopting suitable control measures.

Admittedly throughout the year the majority of mites are ensconced within the bulbs in positions inaccessible to either spray fluid or fumigant. However, as need hardly be mentioned, it is the accepted practice periodically to subject dormant narcissus bulbs to the hot-water treatment. This treatment is for the purpose of controlling certain major pests, particularly bulb eelworm, *Anguillulina dipsaci*, and the larvae of the narcissus fly, *Merodon equestris*. The technique of the process need not be enlarged upon here, but essentially it consists of immersing the bulbs in water maintained at a temperature of 110°F. for a definite period of time, the period varying from one to three hours according to the circumstances and to the size of the bulbs. An immersion for one hour, the minimum treatment given normally, results in a 100 per cent. kill of bulb-scale mite, *Tarsonemus approximatus* var. *narcissi*. In the main, therefore, the problem of controlling this pest resolves itself into the necessity of rather more frequent subjection of bulbs to the hot water treatment than is the general practice. Annual treatment would unquestionably maintain a high and adequate measure of control. There are, however, in the present state of knowledge, certain practical objections, apart from the costliness of the procedure, to such frequent treatment. These apply in particular to stocks required for immediate sale. By way of compromise it is suggested that bulbs be lifted and treated biennially, a measure already in force on certain of the larger and more progressive bulb farms. By this means an adequate check should be given at least to this particular pest and far less complaint as to "degeneration" of narcissus stocks would be heard. It is found that the mites rapidly succumb in the absence of the host-plant, hence reinfestation of treated bulbs, unless placed immediately adjacent to heavily infested ones, is likely to be a singularly slow process.

It is difficult to achieve a reasonable measure of control in the growing bulb. In the field nothing can be done, except that stocks should be examined in May for symptoms of attack. Where infestations are noted the bulbs should, at the conclusion of the growing season, be lifted and treated. By this means serious loss may be avoided. In the forcing bulb the matter is of much greater urgency. For practical reasons bulbs selected or purchased for forcing are unlikely to have been subjected to hot water treatment within the preceding ten or twelve months. They may therefore be infested to a degree which presents grave danger to the flower crop in the forcing house. It has been found, on a small scale, that spraying, as soon as the leaf tips part, with a white oil emulsion will effect a sufficient measure of control to enable a satisfactory flower crop to be produced. Careful examination at the stage of growth mentioned above will always disclose the presence of the mites at least in small numbers if the infection is sufficiently heavy to jeopardise the flower crop. To be effective the spraying must be liberal and the fluid must be directed well into the centres of the bulbs. Unfortunately unless a very careful watch is kept infection is not diagnosed until the injury is beyond repair. It therefore is important that forcing bulbs be examined carefully and critically very shortly after moving into the forcing house. If mites be detected even in comparatively small numbers immediate action is called for, otherwise a greater or lesser percentage of the flowers is likely to be of little or no market value.

Finally it must again be stressed that in the majority of cases in which the poor quality of the bulbs or faulty culture is blamed for poor cropping in the forcing house, bulb-scale mite is the real culprit. Similarly in the field stocks of bulbs which for no very apparent reason fail satisfactorily to increase and lack general vigour will likewise be found on careful examination to be infested. It is of the utmost importance to realise that superficially the symptoms of attack, except in extreme cases, both in forcing house and field, are practically indistinguishable from the mosaic infection known as "Yellow Stripe," and unquestionably the not infrequent cases of reputed recovery from mosaic after hot water treatment are due entirely to a faulty diagnosis having been made in the first instance.

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APPENDIX.

By W. C. MOORE,

*Pathological Laboratory, Harpenden.**Note on a probable early record of a Tarsonemus on Narcissus in England.*

Whilst looking up records of plant diseases in the "Gardeners' Chronicle" recently I found an interesting note which would appear to support the opinion expressed by Hodson in the foregoing paper that the bulb-scale mite is no very new phenomenon to this country but has probably been overlooked in the past. About forty years ago daffodil-growers were greatly troubled by an obscure malady usually referred to as Basal Rot. This name is now retained for a specific fungus disease caused by *Fusarium bulbigenum*, Cooke & Mass., but formerly it was evidently used more or less indiscriminately to include bulb rots resulting from a variety of causes. In March 1892 specimens of one form of Basal Rot were exhibited at a meeting of the Scientific Committee of the Royal Horticultural Society by the Rev. W. Wilks. These were examined later by Mr. A. D. Michael, who reported (J. Roy. Hort. Soc. **15**, 1893, p. xxvii; also in Gard. Chron. (3) **11**, 1892, pp. 440, 534) that two species of *Acarus* were present in them. One was a species of *Rhizoglyphus*, probably *R. echinopus*, stated to be a well-known destroyer of bulbs. The other, which occurred in great numbers but could not be detected without the aid of a microscope, was identified as a species of *Tarsonemus* "most like *T. oryzae* (of Targioni-Tozzetti)." Michael believed this to be the first record of *Tarsonemus* in subterranean structures and considered that it was doing more damage to the bulbs than the *Rhizoglyphus*. Further details given two years later by E. H. Jenkins (Basal Rot in Daffodils—Gard. Chron. (3) **15**, 1894, p. 558) revealed that the specimens examined by Michael consisted of three bulbs (two of the Tenby Daffodil and one of *Narcissus biflorus*) which had most probably been grown in Middlesex.

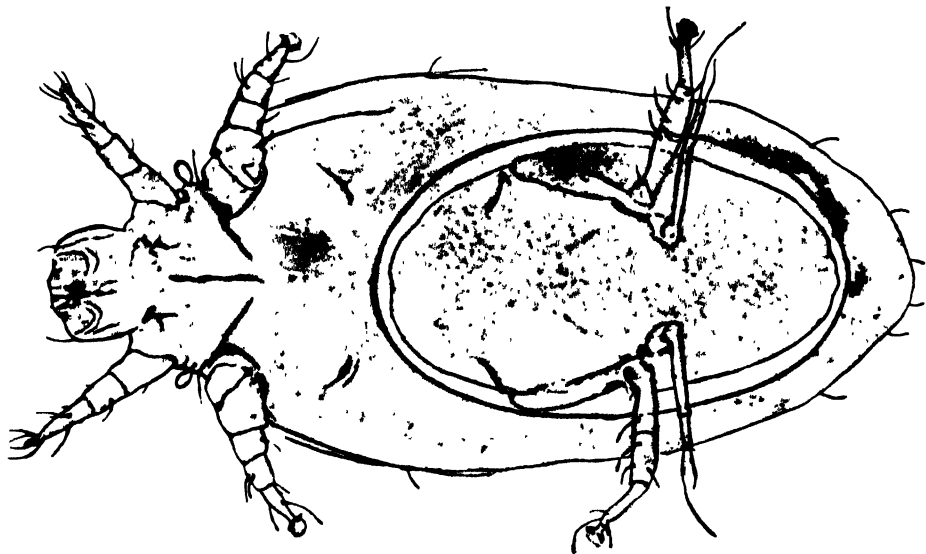


Fig. 2. *T. approximatus* var. *nareissi*, adult ♂, showing egg within the body (greatly enlarged).

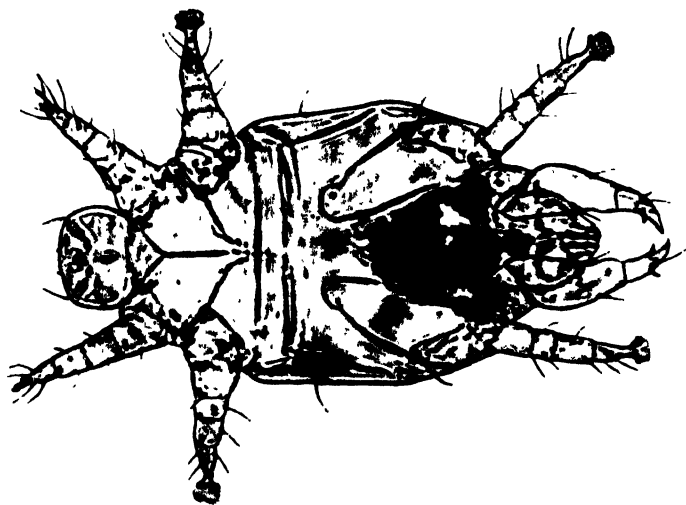


Fig. 1. *T. approximatus* var. *nareissi*, adult ♀ (greatly enlarged).



Transverse and longitudinal sections through narcissus bulb showing typical injury by bulb scale mite

A NEW SPECIES OF COREIDAE (HETEROPTERA) INJURIOUS TO COCONUT IN THE SOLOMON ISLANDS.

By W. E. CHINA, M.A.,
British Museum (Nat. Hist.).

In the British Solomon Islands Protectorate Agricultural Gazette (1 no. 3, pp. 2-3, pl. i, July 1933) Mr. R. J. A. W. Lever has described and illustrated the life-history of a Coreid which is injurious to the inflorescence of the coconut palm. This species which had previously been provisionally referred to the genus *Dasynus* now proves on further investigation to be referable to the closely allied genus *Amblypelta*, and is herewith described.

***Amblypelta cocophaga*, sp. nov.**

Colour.—Head pale greenish yellow (green in life) obscurely infusate dorsally, eyes dark brown, ocelli red; a brown stripe down side of each jugum, continued on to antenniferous tubercle, posterior margin of ocellus with a small brown spot;

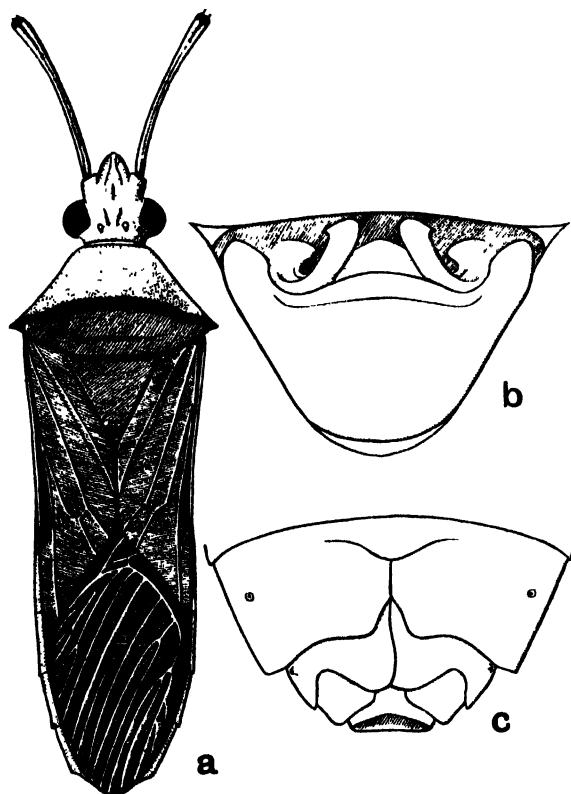


Fig. 1. *Amblypelta cocophaga*, sp. nov.: *a*, dorsal view to show colour pattern and structure of humeral angles; *b*, terminal view of male pygophor, showing parameres; *c*, ventral view of female genital plates.

antennae pale ferruginous, the base and apex of first antennal segment black, the black ends connected by a narrow dorsal brown stripe, extreme apices of second and third segments black, fourth segment missing in type material; rostrum pale

sordid yellow, its apex black. Pronotum pale greenish yellow (green in life), the posterior third ferruginous, the anterior margin of ferruginous region anteriorly convex between the black shining humeral angles; pleura pallid yellow with a short longitudinal black stripe behind each eye. Scutellum ferruginous, its extreme apex black. Hemielytra ferruginous, the costa narrowly pale yellow, inclining to fuscous towards apex of corium, basal half of costal cell intense black forming a narrow black stripe down outer margin of corium to level of inner angle of membrane, which is smoky hyaline; apical half of costal cell bright red. Legs sordid yellow, the middle and posterior femora and tibiae inclined to ferruginous apically, claws black. Dorsum of abdomen red, the lateral margins of apical abdominal tergites black; connexivum yellow; venter sordid yellow.

Structure.—Head densely but finely punctate, nearly twice as long as wide between eyes (43:24), bucculae moderately prominent, very little longer than antenniferous tubercle; rostrum extending to middle of second abdominal segment, first segment extending to anterior margin of prosternum; basal antennal segment about twice as long as head, relative lengths of antennal segments 87:99:65 (missing). Pronotum thickly, coarsely punctate, with the humeral angles fairly prominent, acute and smooth shining black. Scutellum somewhat rugosely punctate, lateral margins lacvigiate. Clavus and corium densely but more finely punctate than pronotum, membrane extending beyond apex of abdomen, which is more or less parallel-sided with the apical angles of connexival segments very feebly prominent. Genitalia figured.

Total length 15 mm., breadth across humeral angles 5 mm.

BRITISH SOLOMON IS.: Tulagi (type ♀), vii.1932; Su'u, Malaita, 1♂, 1♀, vii.1931; Kookoom, Guadalcanal, 1♀, 1931, on coconuts (*R. J. A. W. Lever*).

Additional food-plants: *Macaranga tanarius* and another unnamed Euphorbiaceous shrub, and a *Ficus* sp.

Apparently closely allied to the genotype, *Amblypelta bilineata*, Stål, from New Caledonia, but differing in the relative lengths of the antennal segments, the first being much longer than the third, and in the presence of a black stripe down the costal cell.

The genus *Amblypelta* was established by Stål in 1873* to hold two species, the genotype above mentioned and *A. nitida*, Stål, from Queensland. He distinguished it from *Pendulinus*, Thunb. (*Dasynus*, auct.) by the equilateral, apically truncated scutellum. Neither of Stål's two species is represented in the British Museum collection, but *Pendulinus lutescens*, Dist., described from Queensland, should be referred to this genus, and there are also four more undescribed species represented by single specimens from New Guinea, Lombok, Brisbane and Kei Is. respectively. This extends the range of this genus over the whole Austro-Oriental Region. Stål's subgenera of *Pendulinus*, described in the same work, should be given generic rank, and I herewith fix the genotypes:—(1) *Galaesus*, Dall. 1852, logotype *P. hasticornis*, Thunb., replaces *Pendulinus*, Thunb. 1822, preoccupied by *Pendulinus*, Vieillot 1816 (Aves). (2) *Theraptus*, Stål 1859, haplotype *Chariesterus carmelita*, Burm.; *P. devastans*, Dist., from the Congo, and *P. nigromarginatus*, Dist., from Natal, belong to this genus. (3) *Dasynus*, Burm. 1834, haplotype *Coreus coccocinctus*, Burm. (4) *Odontoparia*, Mayr 1865, haplotype *O. nicobarensis*, Mayr.

Pendulinus fimbriatus, Dist. (Transvaal) is generically distinct. It differs from *Dasynus* in the non-exserted head with small eyes; antennae shorter and more robust, the first segment scarcely longer than the head, first and third segments sub-laminate; the anterior lateral angles of pronotum acute, pronotal collar absent

* Kongl. Svenska Vet. Ak. Handl. xi, no. 2 (Enum Hemipt. iii) p. 74, 1873.

and lateral margins of pronotum sub-carinate throughout. For this species I therefore propose the name **Anadasynus**, gen. nov. *P. rostratus*, Dist. (Bombay), with the very prominent humeral angles and long porrect head with ante-ocular region longer than postocular, represents still another new genus, for which I propose the name **Paradasynus**, gen. nov. *Dasynus piperis*, China, from Banka Is., and *Pendulinus antennatus*, Kirby, from Ceylon, seem to be more closely related to the African genus *Theraptus*, Stål, than to the Oriental genus *Dasynus*, from which they differ in their more slender form, long slender antennae, more prominent humeral angles and sparser puncturation; but the head is more porrect than in *Theraptus*. For the moment, however, it is preferable to retain these species in the genus *Dasynus* together with the aberrant *Pendulinus orientalis*, Dist., from India.

A NOTE ON MOSQUITOS BREEDING IN TREE-HOLES IN NORTHERN NIGERIA.

By A. W. TAYLOR, M.Sc.

The presence in Southern Nigeria of a well defined group of mosquitos whose breeding is confined to holes in trees has been known for some time, and Dalziel (1920) recorded a number of such species from Lagos.

The fact that *Aedes aegypti*, the principal, if not the only, vector of yellow fever, is amongst the tree-hole-breeding species, led to an intensive study of mosquito-breeding in tree-holes by Dunn (1926, 1927a, 1927b), the study being carried on in and around Lagos. Additional interest and importance attached to these studies following transmission experiments with yellow fever which showed several other of the tree-hole-breeding members of the genus *Aedes* to be potential vectors of the disease.

It will be noted that the work cited above was carried out in and around Lagos in the Southern Provinces, where the annual rainfall averages about 70 inches, fairly evenly distributed throughout the year. The climate is humid, and an incomplete dry season only lasts for about two months. Such conditions are obviously favourable to species which depend for their survival on the presence of collections of rain-water in rot-holes in trees.

In Northern Nigeria a very different climate is found. At Gadau, where this work was done, the majority of the annual rainfall, which averages 25 inches, occurs during the three months from mid-June to mid-September, the remainder of the year being dry. During the dry season humidity is extremely low, and the temperature subject to great daily variation. Early in the dry season grass fires sweep through the open scrubby bush, and frequently the flames from these fires scorch the topmost branches of the trees. Such conditions seemed likely to make impossible the survival of tree-hole-breeding mosquitos.

It was found by Kumm (1931), however, that *Aedes metallicus*, a suspected potential vector of yellow fever, was breeding in tree-holes at Kano in N. Nigeria, and in the same year observations were commenced at Gadau.

Eleven tree-holes were located within convenient distance of the European station at Gadau and these were kept under observation for a year. The trees in which the holes (usually rot-holes) occurred were of the following species: *Adansonia digitata* (baobab), 2; *Tamarindus indica* (tamarind), 2; *Anogeissus leiocarpus*, 2; *Stereospermum kunthianum*, 2; *Khaya senegalensis* (African mahogany), 1; *Parkia filicoidea* (locust bean), 1; *Acacia seyal* (gum acacia), 1. No evidence was obtained that species of tree-hole-breeding mosquitos show any preference for particular species of trees.

Although a few showers fell during May and June, no rain-water remained longer than a few hours in any of the tree-holes until the beginning of July 1931. From then until the tree-holes dried up finally in the second week of September, periodic samples of the water contained in the 11 holes were made, and the larvae present were bred out in the laboratory.

Table I summarises the species of tree-hole-breeding mosquitos found in this way and the number of holes in which they were found.

Comparison of this list of species with similar lists from Southern Nigeria shows the composition of the tree-hole mosquito fauna of the North to be very different

from that of the South. Species abundant in tree-holes in the North but absent in the South are *Aedes metallicus*, *A. furcifer* and *A. unilineatus*; *Aedes simpsoni*, an uncommon species in the South, is abundant in the North. Species abundant in tree-holes in the South but unrepresented in the Gadau survey include *Aedes africanus*, *A. stokesi*, *A. apicoargenteus*, *A. wellmani*, and *A. longipalpis*; but it would obviously necessitate a more comprehensive survey before it could be stated that these species are absent from the North.

TABLE I.

List of Species of Mosquitos bred from Larvae found in Collections of Rain-water in eleven Tree-holes at Gadau, July-September 1931.

Species						Number of tree-holes in which found
<i>Aedes metallicus</i>	...	...	...	...	...	8
<i>Aedes furcifer</i>	...	...	...	...	...	7
<i>Aedes simpsoni</i>	...	...	...	...	...	6
<i>Aedes luteocephalus</i>	...	...	...	...	...	5
<i>Aedes aegypti</i>	...	...	...	...	...	3
<i>Aedes unilineatus</i>	...	...	...	...	...	3
<i>Culex nebulosus</i>	...	...	...	...	...	9
<i>Culex decens</i>	...	...	...	...	...	1
<i>Megarhinus brevipalpis</i>	...	...	...	...	...	1

Of the *Aedes* species found in the Gadau survey (apart from *A. aegypti*), *A. luteocephalus* and *A. simpsoni* are proven experimental vectors of yellow fever, and there is no reason to suppose that the other species (*A. metallicus*, *A. furcifer*, and *A. unilineatus*) could not also transmit this disease. The presence of these species in Northern Nigeria is thus of some importance, although recent work (Becuwkcs, Kerr, Weathersbee, and Taylor, 1933) suggests that the experimental transmission of yellow fever by species other than *A. aegypti* is probably of academic interest only. After the survey during the wet season of 1931 it remained to investigate during the succeeding dry season whether the eggs of the tree-hole-breeding species remained viable, especially after the grass fires which normally are over by early December. A similar investigation by Ingram in the Northern Territories of the Gold Coast (1919) gave negative results and led this author to write: "It seems open to doubt whether *S. fasciata* and other spp. of this genus tide over the dry season in the Northern Territories by means of resistant eggs stranded in rot-holes of trees."

In January and February 1932 the writer made collections of debris and scrapings from the eleven tree-holes. These were placed in water, any larvae emerging were hatched out, and the information obtained is summarised in Table II.

From this table it is seen that eggs of the tree-hole-breeding *Aedes* of the Northern Provinces remain viable during the dry season. That only four of the six species of *Aedes* recorded in Table I should have been bred out is almost certainly due to the small number of tree-holes examined during the survey.

It has thus been seen that a true tree-hole mosquito fauna exists in the Northern Provinces of Nigeria, at least as far North as latitude 12°N. at Gadau. Amongst this fauna are found *A. aegypti*, *A. luteocephalus*, and *A. simpsoni*, all of which have been proved to be capable of transmitting yellow fever by bite. The eggs remain viable in dry condition through a long and very rigorous dry season, tree-hole breeding only being possible during the height of the wet season, a period extending over less than three months of the year.

TABLE II

List of Species of Mosquitos bred from dry Material collected from eleven Tree-holes at Gadau, N. Nigeria, January and February 1932

Species						Number of tree-holes from which obtained
<i>Aedes simpsoni</i>	10
<i>Aedes unilineatus</i>	5
<i>Aedes metallicus</i>	2
<i>Aedes aegypti</i>	1

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THE BEHAVIOUR OF THE LARVAE OF TSETSE-FLIES BEFORE PUPATION.

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(PLATE X.)

Introduction.

The larva of *Glossina* after completing its development in the uterus of the parent fly is deposited on the soil, into which it burrows, and pupates within an hour of deposition. The behaviour of the larva at this time is of great importance in determining its chances of survival. If it is slow to penetrate the soil it is exposed for a longer period to the possible attacks of predators and parasites, and on the depth to which it burrows depends the position which it will occupy as a puparium during the succeeding weeks. The greater the depth, the less will be the exposure to certain predators and parasites, and to the effects of solar radiation.

The tsetse larva, being adapted to an intra-uterine life, differs greatly from free-living larvae of Cyclorrhaphous Diptera. These are generally well adapted for locomotion; the larva of *Musca domestica*, for instance, can crawl rapidly by means of the large hooks of the cephalo-pharyngeal armature and of the recurved spines which cover the crescentic pads on the ventral surface of the abdomen (Hewitt, 1914). An extremely efficient burrowing method is that of the young parasitic larva of *Cordylobia anthropophaga*, which can penetrate mammalian cuticle in a few seconds by using the buccal armature (Blacklock & Thompson, 1923). In *Glossina*, however, the cephalo-pharyngeal armature is reduced to basal sclerites (Keilin, 1916) and is therefore of no use in locomotion. The only anterior protuberances are the minute fused antennae and maxillary palpi. The cuticle bears no spines but is granulated (Newstead, 1924). The larva moves and burrows by peristaltic movements and longitudinal contractions of the whole body, and also, as Keilin suggests, makes use of the antenno-maxillary appendages in progression.

Observations.

It was desirable to know more of the behaviour of newly deposited larvae because it was found that several larvae of *Glossina tachinoides*, Westw., and *G. submorsitans*, Newst., failed to burrow when placed on sifted sand but pupated on the surface. The following notes were made at the Tsetse Investigation Laboratory at Gadau in Northern Nigeria in the course of work on the puparia and adults of these species (Buxton & Lewis, 1934).

The accompanying photograph (Plate X) shows a larva of *G. submorsitans* which was unable to burrow in sand composed of particles 0.2-1.0 mm. in diameter. Its tracks on the surface are seen leading to the place where it lies, about to pupate. The track consisted of a series of small pits, each corresponding to two distinct movements of the larva, a peristaltic wave of contraction passing forward along the body, and a longitudinal contraction which pulled the posterior segments towards the head. The peristaltic movement was much like that observed by Roubaud (1909) in *G. palpalis*, although the changes of shape were not so great as those shown in his figures. The longitudinal contraction was followed by a pause during which the head and first two or three segments of the body were moved rapidly from side to side three or four times. The cephalic appendages were clearly visible and, if the larva

were beneath the soil, would evidently be used for pushing aside particles and preparing the way for another peristaltic movement of the body and forward extension of the head into fresh soil. This cycle of movements was generally very regular; in a larva of *G. submorsitans* a few minutes after deposition the numbers of complete movements in three successive minutes were 20, 18 and 20. An hour later the numbers were 25, 28 and 28. This larva was placed on wood ash and immediately began to move forward, constantly changing direction. Being unable to burrow, it continued crawling on the surface for more than an hour after deposition. The speed was variable. After half an hour the larva was crawling at the rate of 0.8 to 2.1 cm. a minute. During five minutes it covered a distance of 7.9 cm., but owing to its crooked path, was only 3.8 cm. from its starting point. Half an hour later it travelled 9.8 cm. in five minutes, but finished 2.3 cm. from the starting point. The room temperature was about 30°C. For comparison, larvae of *Calliphora erythrocephala* were subsequently placed on the same substratum and found to move at about 18 cm. a minute. They could burrow in 20 seconds, sweeping away the ash with their prominent buccal hooks. Unlike those of *Glossina*, these larvae moved in a straight line away from the source of light.

Table showing the numbers of larvae of *Glossina tachinoides* and *G. submorsitans* which burrowed in wood ash and boxes of sifted sand of different coarseness. The asterisks indicate those larvae which were weighed.

Medium	Diameter of particles mm.	<i>tachinoides</i>		<i>submorsitans</i>	
		No.	% below surface	No.	% below surface
Wood ash	0 -1.0	84*	8	36	31
Sand	0 -0.2	100*	49	58*	47
Sand	0.2 1.0	94*	79	84*	92
Sand and stones	0 -0.2	141	80		
Sand from river bed		41	100		
Sand from burrow		38	92		

The time which elapsed between the deposition of the larva and pupation was variable. For larvae of *G. tachinoides* which were unable to burrow it was about 40 minutes. One larva of *G. submorsitans* pupated after 2 hours, and another failed to pupate after remaining alive for 3 days. This was probably due to premature deposition. Roubaud (1909) found that larvae could delay pupation if they were not able to burrow at once. Also Potts (1933) observed that larvae of *G. morsitans* became rigid and motionless in a quarter of an hour if they burrowed in sand, but that more than one hour elapsed if they were on a hard surface.

Many larvae which were placed on sand at Gadan were unable to burrow unless they came in contact with pebbles sufficiently heavy to give them purchase. The bodies of other larvae were too light for this purpose. A larva of *C. submorsitans* on sand (0.2-1 mm.) under a glass microscope slide burrowed to a depth of 5 mm. but repeatedly reappeared until the soil was sprinkled with water. To test the burrowing powers of large numbers of larvae, trays of sand of different coarseness were placed one inch beneath breeding-cages containing adult tsetse-flies, the larvae which they produced falling through coarse wire gauze. The table shows the results, and it is seen that in both species more larvae burrowed in coarse than in fine sand, and more in sand than in wood ash. When small stones about half an inch in diameter were

placed on the fine sand (0.2 mm.), 79 per cent. of the larvae burrowed, although only 49 per cent. had been able to do so with no stones present. The number of stones (one to six) made little difference. The highest proportion of larvae burrowed in two samples of sand from a breeding-place of *G. tachinoides* in a river-bed and from the burrow of an aard-vark. The proportion by weight of particles under 0.2 mm., 0.2-1 mm. and over 1 mm. in diameter were respectively: 4, 86 and 10 per cent. in the river sand, and 41, 58 and 1 in that from the burrow. Several hundreds of the larvae were weighed after pupation, as it appeared probable that heavier larvae, which made a deeper furrow when crawling, might burrow more easily. The differences between the mean weights of those which burrowed and those which did not were small, 0.48 mg. in *G. tachinoides* and 0.49 mg. in *G. submorsitans*. Weights of fresh puparia bred in the laboratory, moreover, had a wide range of variation (Buxton & Lewis, 1934) and many heavy and light larvae occurred in each group. It is evident, therefore, that burrowing efficiency has little or no relation to the weight of the larva. Moreover, the mean weight of *G. submorsitans* puparia on the first day was 8 mg. higher than that of *tachinoides*, but there was little difference between the burrowing efficiency of the two species, except for larvae on wood ash.

Previous Work.

The importance of the depth to which larvae burrow has been noticed by Fiske (1920). He records a breeding-place of *G. palpalis* in which "there was a layer of vegetable debris under fern and over pebbles that had been packed so firmly by the body of the *Varanus* (lizard) that the larvae could only penetrate with difficulty. Many were forced to form puparia only half concealed and of these all were destroyed." Another place is described as a "perfect death trap," where the hard clay and gravel in a shaded place were unsuitable for larval burrowing and no puparia were found which had survived for more than a few hours. Fiske gives a table showing the number of damaged pupal shells, in proportion to the total number collected, in different types of soil. His figures indicate that the death-rate from predators is low in "vegetable debris"—3.5 per cent. (excluding the example of *Varanus* mentioned above), but high in "very fine white sand"—17.1 per cent. Other sands and gravels show various intermediate death-rates. This result would be expected from the knowledge that larvae burrow more easily in coarse sand. Fiske, however, expected to find a higher mortality in coarse soil owing to the burrowing of predatory insects. The burrowing powers of the parasite, *Syntomosphyrum glossinae*, have been studied by Nash (1933), who found that they could only burrow 0.1 inch in dry sand and about 0.5 inch in dry humus. The female would therefore be unlikely to reach many tsetse puparia buried in sand, but he records the larva of *G. morsitans* being successfully parasitised in the laboratory before it could penetrate the soil.

In addition to being endangered by other insects, a larva which can only burrow a few millimetres may be subjected to considerable changes of temperature. Nash buried puparia at different depths in the soil in September in Tanganyika Territory, and found that in an unshaded position the sun could raise the temperature of the soil above the thermal death point of the puparia to a depth of $1\frac{1}{2}$ inches, greater than that at which puparia generally occur.

Laboratory observations have been made on the burrowing of larvae of several species of *Glossina*. Thus Stuhlmann (1907) found that those of *G. fusca* and *G. tachinoides* could burrow 8.5 cm. deep in damp sand, but only 2 to 3 cm. in dry sand; and Roubaud (*loc. cit.*) gives somewhat similar figures for *G. palpalis*. Croveri (1919) observed larvae of *G. pallidipes* to become motionless half an hour after burrowing about 1.5 cm. deep in sand, and Kinghorn (1911) records larvae of *G. morsitans* burrowing immediately when placed on dry powdered earth.

Records of natural breeding-grounds of *Glossina* show that puparia often occur in sandy soil which has no hard crust and is dry at all seasons (Lamborn, 1916), and

Duke (1918) found puparia of *G. palpalis* in sand but not in the tough humus of the forest zone. It is interesting to compare the figures in the table on p. 196 with those given by Johnson & Lloyd (1922) of the numbers of puparia of *G. tachinoides* in different types of soil. Of over 8,000 collected, 7,540 were found in coarse sand, 525 in fine sand, 113 in wood ash, 80 in cracks in baked mud, 8 in fibrous loam, and 2 in gravel. The great difference in numbers in coarse and fine sand may be due either (1) to the selective habits of the female fly, (2) to the larvae being able to burrow more readily in coarse sand, or (3) merely to a greater area of coarse than of fine sand being available. These authors found 300 puparia in sand in one angle of a fig tree and none in another angle which contained hard mud. If, as Swynnerton (1920) suggests, the female does not select the breeding-place but merely drops the larva from where she happens to be resting, the mortality due to predators is probably very high in such a locality, when one considers the very slow movements of the larva searching for loose soil in which to burrow. This conclusion is supported by the following records. Simpson (1917) observed larviposition by a female *G. submorsitans*. "She took up her position on the underside of the trunk and let the larva drop. Within five minutes the larva had penetrated the soil and disappeared." Swynnerton (1920) considers that larvae of *G. morsitans* have to crawl over the surface of hard soil until they find a place where birds or small mammals have scratched and loosened the surface. He found puparia of *G. brevipalpis* which had evidently passed over shaly soil to burrow in patches of humus.

Summary and Conclusions.

Observations in the laboratory on the larva of *Glossina tachinoides* and *G. submorsitans* show that in both species it is slow in crawling and burrowing and often cannot burrow at all. It penetrates coarse sand more readily than fine, and fine sand than wood ash, and burrows easily in fine sand with pebbles. In nature it probably always burrows eventually, unless it is attacked by predators or parasites to which its behaviour renders it vulnerable.

Previous field work indicates that the depth to which the larvae burrow influences the effect of predators and parasites and sometimes of solar radiation on the puparia. Records of breeding-places suggest that larvae often crawl over hard soil to reach suitable places in which to burrow, and that unless the female fly, before depositing a larva, carefully selects such a place, the mortality due to other insects is probably high.

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A larva of *Glossina submorsitans*, West., which was unable to burrow into sand composed of particles 0.2 to 1 mm. in diameter.

THE BIOLOGY AND DISTRIBUTION IN FRANCE OF THE LARVAL PARASITES OF *CYDIA POMONELLA*, L.

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1. Introduction.

The Codling Moth, *Cydia pomonella*, L., is one of the most serious insect pests occurring in the British Empire, and several requests for shipments of its parasites have been received by the Imperial Institute of Entomology. Accordingly, collections of larvae were made in the autumn of 1928, in Northern France, with the object of investigating the occurrence of parasites. The collections of 1928 were not large, totalling approximately 1,000 larvae, and mortality in the hibernating larvae was heavy; the percentage of parasitism being low, the results were found to be inadequate. During the autumn of 1929 and the winter of 1929-30, the collections were resumed on a larger scale, and the range was extended to cover the most important apple-growing centres of France.

2. Areas Surveyed.

Collections of hibernating larvae were made in the two seasons in 17 localities, which may be grouped to form the following 10 areas:—

Department	Locality	Approx. no. of larvae collected in 1928	Approx. no. of larvae collected in 1929-30
i. Seine-et-Oise	Herblay	250	—
	Corneilles-en-Parisis	80	—
	Orgeval	150	—
	Montamet	100	—
	Grignon	—	10,300
ii. Seine Inférieure	Elbeuf	—	20,100
iii. Rhone	St. Laurent-les-veaux	—	400
	Vaugneray	—	200
	Villefranche-sur-Saône	—	100
iv. Loire-et-Cher	Blois	80	—
	Chaumont-sur-Loire	50	—
v. Ille-et-Vilaine	Rennes	140	200
vi. Oise	Beauvais	100	—
vii. Corrèze	Brive	—	400
viii. Calvados	St. Pierre-sur-Dives	—	510
ix. Meurthe-et-Moselle	Toul	—	200
x. Haute Savoie	Annecy	—	200

In addition, a small collection of Codling Moth parasites was made in the neighbourhood of Antibes (A. M.).

No statistics of the production of apples in France are available; but the combined total production of apples and pears in 1931 is given in "Statistique Agricole Annuelle, 1931" (Ministère de l'Agriculture, Paris). As apples and pears are usually grown in the same localities, the figures give some idea of the apple-growing areas of France, and from them fig. 1 has been drawn. The following notes on the distribution of the apple in France, and unacknowledged quotations throughout this paper, are translated from a report of the Laboratory's Field Agent, Mr. S. Kozlovsky, who made the collections: "To understand the distribution of the apple in France, it is

necessary to consider the production of the two national drinks, wine and cider. In the north of France the apple is grown; in the south, the vine. These two zones overlap in a wide strip of country following the Loire, the Marne, and the canal from the Marne to the Rhine. As the vine becomes important, the cider apple disappears. Eating apples are grown in the south, as well as the vine. There are important orchards of eating apples in the Lyonnaise region, the Alpes region, the Massif Central, and in Corrèze."

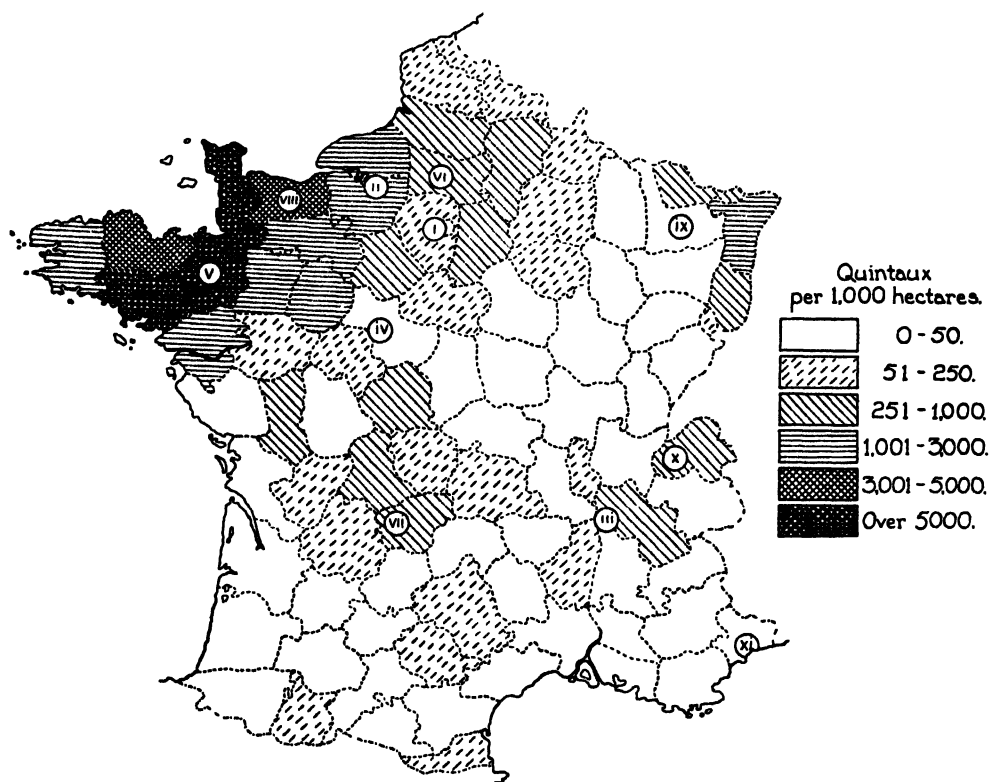


Fig. 1. Map showing production of apples and pears in the Departments of France, in quintaux per 1,000 hectares of cultivated land, in 1931. Figures within circles indicate areas where collections were made, and refer to the list on page 202.

At Elbeuf, bands of corrugated paper were put round the trees during the summer, and the hibernating larvae were collected during the months of September, October and November. At Grignon, no bands had been fixed, but in the orchards of the Ecole Nationale de l'Agriculture iron guards were in position round the trees to protect them from cattle, with sacking between the bars of the guards and the trunks of the trees. These bands of sacking were found to contain very large numbers of larvae. In the other localities no bands were used, and the collections were made by a laborious searching of the trunks. Great credit is due to our Field Agent, Mr. S. Kozlovsky, for the large numbers of larvae which he collected in this way, under the adverse weather conditions obtaining during much of the winter of 1929-30. Mr. Kozlovsky states that the larvae are most abundant on those parts of the trunk which are moderately damp, but not too wet; they are seldom found on parts of the trunk which are moss-covered. On collection, the larvae were put in mailing tins, containing strips of corrugated cardboard, and there allowed to remake their cocoons.

3. Hibernation of Collections.

The collections of larvae, on arrival at the Laboratory, were put in cages in an unheated outdoor insectary. During the winter of 1928-29, the cocoon racks were kept moist by immersion for one minute in water, at intervals of a fortnight, it having been found by Peterson & Haeussler (1928) that such moistening reduces mortality in the hibernating larvae. This procedure was adopted at the commencement of the winter of 1929-30; but the first part of the collections from Elbeuf in this season were attacked by a fungus disease which caused the death of at least 13,000 larvae. The larvae attacked, for the most part, did not respire their cocoons after collection; those which did spin a cocoon made only a thin, flimsy one. The bodies of dead larvae were hard and brittle, pink in colour externally and white internally, most of them being covered by a dense, white felted mass of fungus. Mr. S. F. Ashby, of the Imperial Mycological Institute, to whom specimens of the fungus were sent for identification, stated that it appeared to be *Beauveria globulifera* (Speg.) Pic. To prevent any further spreading of the fungus, the remainder of the collections of 1929-30 were not moistened. The lack of moisture probably increased the larval mortality, which was approximately 60 per cent. in 1929-30, in those batches of larvae not attacked by fungus; but a large number of these larvae died without making new cocoons after collection, this being especially noticeable in collections made during very cold weather in January and February; some of the deaths must be attributed to factors other than the lack of moisture, including low temperature at the time of collection and transmission through post, when some of the larvae were without cocoons.

4. Emergence Records.

It should be noted that in this section, all parasites reared are recorded. In some cases parasites may be from hosts other than Cydia pomonella; or may be secondary parasites. Where a percentage of parasitism is given, however, the host is definitely known to be C. pomonella. The host relationships of the various parasites will be discussed in the succeeding section.

The percentages of parasitism have been calculated as follows:—In the case where the parasite was present at the time of collection as an internal parasite of the larva, the percentage of parasitism given is based on the number of parasites compared with the number of moths plus the total number of parasites emerging in the following spring, it being necessary to assume that under the artificial conditions under which the hibernating larvae were kept, the mortality of hosts and of parasites was identical; in the case where the parasite was present as an ectoparasite, or had spun its cocoon outside the host larva at the time of collection, the percentage is based on the number of host larvae, plus the number of parasites collected. It was necessary to adopt these somewhat unsatisfactory methods of determining percentages, since, the degree of parasitism being small, it was impracticable to find the percentages by dissection.

Mean temperatures have been calculated from figures given by A. Angot (1907).

(i). Department: SEINE-ET-OISE (REGION OF PARIS).

From collections made at Herblay and Corneilles in October 1928, and at Orgeval and Montamet in November 1928, the following emerged:—

431 *Cydia pomonella*, L.

1 *Exorista westermanni*, Zett.

1 *Pristomerus vulnerator*, Panz. (0.23 per cent.).

1 *Trichomma enecator*, Rossi (0.23 per cent.).

4 *Ascogaster quadridentatus*, Wesm. (0.91 per cent.).

A much larger collection was made between 16th November and 12th December 1929 at Grignon, which "is 33 km. west of Paris. The climate is very similar to that

of Paris. Rain is fairly frequent, and there is never very much snow. There is slightly less fog here than at Paris." Mean temperatures: July 18.2°C., January 2.1°C.; annual 9.75°C.

The following emerged :—

3,615 *Cydia pomonella*, L.

43 *Arrhinomyia tragica*, Mg. (1.15 per cent.).

14 *Pristomerus vulnerator*, Panz. (0.38 per cent.).

43 *Ascogaster quadridentatus*, Wesm. (1.15 per cent.).

1 *Perilampus tristis*, Mayr

During the collection of larvae at Grignon, various parasite cocoons and puparia were found and sent to the Laboratory. It is difficult accurately to estimate the percentage of parasitism in these cases, since some parasite larvae were killed in collection, and many, whose cocoons were broken, died. 10,300 *Cydia* larvae were collected. With them 9 puparia of *Arrhinomyia tragica*, Mg., were found; these puparia were hyperparasitised or dead, and are believed to have belonged to an earlier generation. Also 125 cocoons of *Ephialtes extensor*, Tasch., 2 cocoons of *Hemiteles hemipterus*, F. (a hyperparasite of *Ephialtes extensor*) and 50 cocoonless larvae were collected. The *Ephialtes* larvae were not all allowed to develop, but from 51 cocoons :—

31 *Ephialtes* adults emerged ;

8 *Ephialtes* pupae died ;

8 *Ephialtes* larvae died ;

2 *Hemiteles hemipterus* pupae died ;

4 *Dibrachys cavus*, Wlk., emerged from 1 *Ephialtes* cocoon ;

1 Chalcid hyperparasite died.

From the cocoonless larvae the following emerged :—

12 *Ephialtes* adults ;

2 *Eurytoma appendigaster*, Boh. ;

2 *Hemiteles macrurus*, Ths. ;

1 *Hemiteles hemipterus*, F.

Seventeen larvae, 1 prepupa, and 4 pupae of *Ephialtes* died. In 11 cases it was impossible to identify larvae or pupae which died. *Hemiteles hemipterus*, *H. macrurus*, and *Dibrachys cavus* are hyperparasites of *E. extensor*; so it appears that at least 38 of the cocoonless larvae represent parasitism of *Cydia* by *Ephialtes*. Together with the 125 cocoons collected, these total 163 *Ephialtes* individuals, or 1.6 per cent. of the total number of hosts and parasites; while probably about 15 or 16 *Ephialtes* were hyperparasitised.

(ii). *Department* : SEINE INFÉRIEURE.

At Elbeuf collections were made from 7th September to 8th November 1929.

"Elbeuf is situated on the right bank of the Seine, eighteen kilometres from Rouen. It has a maritime climate. There is less rain here than at Rennes, and the summer is warmer and drier than in Brittany. Elbeuf is in the east of Normandy. The cultivation of cider apples is of great importance and where the hills are not covered with woods, they are planted with apples. Orchards of several hundred trees, belonging to one tenant, are common. The trees are very well cared for, as cider apples are one of the principal productions of the country. The trees are young and vigorous. The earth is dug round the trees; and dead branches are regularly removed. The cattle in the pasture are muzzled and cannot damage the trees; young trees are protected by a railing. A first crop is gathered in September and a second at the end of November; for some weeks previously, cattle are not allowed to enter the orchards." Mean temperatures: July 17.4°C.; January 3.0°C.; annual 10.0°C.

The following emerged :—

- 2,566 *Cydia pomonella*, L.
- 43 *Arrhinomyia tragica*, Mg. (1·63 per cent.).
- 18 *Trichomma enecator*, Rossi (0·68 per cent.).
- 1 *Pristomerus vulnerator*, Panz. (0·04 per cent.).
- 11 *Ascogaster quadridentatus*, Wesm. (0·42 per cent.).
- 2 *Dacnusa* sp.
- 1 *Meteorus chrysophthalmus*, Nees.

Some puparia of *Arrhinomyia* were collected, but by mistake were discarded ; these were probably hyperparasitised members of an earlier generation. In the collections of *Cydia* made during September (which were attacked by fungus) *Arrhinomyia* was more abundant than in the later collections ; in the earlier lots, 29 *Arrhinomyia* emerged with 740 moths, or 3·71 per cent. A considerable number of Codling Moth pupae were received ; these were pupae of the first and second generations. In them were present :—*Dibrachys affinis*, Masi, as a parasite of *Cydia pomonella* pupae ; *D. cavus*, Wlk., as a parasite of a *Cydia pomonella* pupa, from which the adult moth was about to emerge, and as a hyperparasite of *Arrhinomyia* puparia ; *Eurytoma appendigaster*, Boh., and *Monodontomerus dentipes*, Boh., as hyperparasites of *Arrhinomyia* puparia.

The collections at Elbeuf were made early in the autumn of 1929, at which time the ectoparasites of the species, *Ephialtes extensor*, Tasch., had not completed their development. Mr. Kozlovsky informs me that many *Ephialtes* eggs and immature larvae were collected, and that of these at least 90 per cent. were killed, or died without making their cocoons for hibernation. From 14 *Ephialtes* cocoons received at the laboratory, 10 adults and no hyperparasites emerged. In addition, the following were received, in all cases without the remains of their hosts, and so not definitely known to be parasites of *Cydia pomonella* :—

- 7 cocoons of *Meteorus chrysophthalmus*, Nees.
- 2 cocoons of *Hemiteles hemipterus*, F.
- 1 cocoon of *Hemiteles* sp. (probably *H. hemipterus*, F.).
- 1 cocoon of *Eupelmus urozonus*, Dalm.
- 5 Chalcid larvae, *Dibrachys cavus*, Wlk.

Assuming that the three cocoons of *Hemiteles* sp. present were those of hyperparasites of *Ephialtes*, that the 5 Chalcid larvae came from one *Ephialtes* cocoon, and that 90 per cent. of the *Ephialtes* larvae were killed, the number of *Ephialtes* larvae collected with approximately 20,000 *Cydia* larvae was only 180, of which about 40 were parasitised. Had the collections been made later, when the *Ephialtes* females had finished ovipositing, and the *Ephialtes* larvae had all completed their development, the percentage might have been higher.

(iii). *Department* : RHONE (REGION OF LYONS).

" Here I have visited three centres : two mountainous, St. Laurent-les-veaux and Vaugneray, which are on the edge of the Massif Central, and one in the valley, Villefranche-sur-Saône. St. Laurent-les-veaux is a little village some twenty kilometres east of Lyons. The orchards visited are on the slope of a mountain facing the east, and forming the side of a rather narrow valley. The winds are strong here, and the winter temperature is rather low. The ground under the trees is usually cultivated. The condition of the trees left much to be desired. Not far from the above village is Vaugneray. The situation of the orchards and the conditions therein are similar to those found at St. Laurent-les-veaux ; but the exposure of the orchard was towards the south. Villefranche-sur-Saône lies in the valley of the Saône, to the north of Lyons. The orchard here visited is situated in a secondary valley on the borders of the Mont d'Or. It had been neglected for several years, but was being put in good order once more."

Mean temperatures: Lyons—July 20·6°C.; January 1·9°C.; annual 11·0°C.

Villefranche-sur-Saône—July 20·1°C.; January 1·7°C.; annual 10·8°C.

From collections made at St. Laurent-les-veaux (19th–25th December 1929), Vaugneray (26th December 1929–5th January 1930), and Villefranche-sur-Saône (8th–13th January 1930), the following emerged:—

247 *Cydia pomonella*, L.

1 *Arrhinomyia tragica*, Mg. (0·39 per cent.).

1 *Pristomerus vulnerator*, Panz. (0·39 per cent.).

1 *Ascogaster quadridentatus*, Wesm. (0·39 per cent.).

8 *Trichomma enecator*, Rossi (3·11 per cent.).

With 700 *Cydia* larvae, there were collected:—

24 *Arrhinomyia tragica*, Mg., puparia;

78 *Ephialtes extensor*, Tasch., cocoons.

From the *Ephialtes* cocoons there emerged 41 *Ephialtes* and 3 *Hemiteles* sp. In addition 5 cocoons were parasitised by Chalcids.

(iv). *Department*: LOIRE-ET-CHER.

From collections made at Chaumont-sur-Loire (11th August 1928) and Blois (15th August 1928) there emerged:—

83 *Cydia pomonella*, L.

2 *Trichomma enecator*, Rossi (2 per cent.).

1 *Arrhinomyia tragica*, Mg. (1 per cent.).

11 *Pristomerus vulnerator*, Panz. (11 per cent.).

1 *Ascogaster quadridentatus*, Wsm. (1 per cent.).

2 *Perilampus laevifrons*, Dalm.

No collections of ectoparasites were made.

Mean temperatures for Blois and Chaumont-sur-Loire: July 19·1°C.; January 2·7°C.; annual 10·9°C.

(v). *Department*: ILLE-ET-VILAINE.

Collections were made at Rennes from 24th August to 14th September 1928.

"The climate here is distinctly maritime. Temperatures are equable. There is little snow, but rain is very frequent. The collection of caterpillars was made at l'Ecole des Trois Croix; the orchard is low-lying, damp, and almost covered with water after heavy rain. The trees are fairly well cared for, although many are old."

Mean temperatures: July 17·8°C.; January 3·9°C.; annual 10·6°C.

The following emerged:—

104 *Cydia pomonella*, L.

3 *Pristomerus vulnerator*, Panz. (2·75 per cent.).

1 *Trichomma enecator*, Rossi (0·92 per cent.).

1 *Ascogaster quadridentatus*, Wsm. (0·92 per cent.).

No collections of ectoparasites were made.

Further collections were made here from 27th January to 6th February 1930.

The following emerged:—

73 *Cydia pomonella*, L.

2 *Arrhinomyia tragica*, Mg. (2·63 per cent.).

1 *Ascogaster quadridentatus*, Wsm. (1·31 per cent.).

In addition, with 200 Codling Moth larvae, there were collected 7 cocoons of *Ephialtes extensor*, Tasch., from which 4 *Ephialtes* and 1 *Hemiteles macrurus*, Ths., emerged.

(vi). *Department*: OISE.

A collection was made at Beauvais on 18th September 1928.

Mean temperatures: July 17·9°C.; January 2·0°C.; annual 9·7°C.

The following emerged :—

- 84 *Cydia pomonella*, L.
- 1 *Pristomerus vulnerator*, Panz. (1·14 per cent.).
- 2 *Trichomma enecator*, Rossi (2·27 per cent.).
- 1 *Ascogaster quadridentatus*, Wsm. (1·14 per cent.).

No collections of ectoparasites were made.

(vii). *Department* : CORRÈZE.

A collection was made at Brive from 19th to 25th January 1930.

Mean temperature : July 20·3°C. ; January 3·1°C. ; annual 11·7°C.

"The climate here is somewhat similar to that of the south of France. There is much rain at Brive in winter. The summer is usually dry and fairly warm. There are not many apple trees here, although they grow well. Eating apples only are grown here. The trees are very badly looked after."

The following emerged :—

- 83 *Cydia pomonella*, L.
- 1 *Arrhinomyia tragica*, Mg. (1·12 per cent.).
- 1 *Pristomerus vulnerator*, Panz. (1·12 per cent.).
- 3 *Ascogaster quadridentatus*, Wsm. (3·37 per cent.).
- 1 *Perilampus tristis*, Mayr.

In addition, there were collected, with 400 larvae of *Cydia pomonella*, 18 larvae of *Ephialtes extensor* and 3 larvae, believed to be *Hemiteles* sp., hyperparasites of *Ephialtes*. From the larvae of *Ephialtes*, 11 adults and no hyperparasites emerged.

(viii). *Department* : CALVADOS.

A collection was made at St. Pierre-sur-Dives from 19th February to 6th March 1930.

Mean temperatures : July 17·3°C. ; January 3·7°C. ; annual 9·07°C.

"The climate is maritime, mild in winter and not excessively hot in summer. There is much rain, but snow is rare. Cider apple trees are very abundant. The trees are fairly well cared for."

The following emerged :—

- 76 *Cydia pomonella*, L.
- 1 *Arrhinomyia tragica*, Mg. (1·19 per cent.).
- 1 *Trichomma enecator*, Rossi (1·19 per cent.).
- 3 *Pristomerus vulnerator* Panz. (3·57 per cent.).
- 2 *Ascogaster quadridentatus*, Wsm. (2·38 per cent.).
- 1 *Perilampus tristis*, Mayr.

With 510 larvae, there were collected 26 cocoons of *Ephialtes extensor* and 1 puparium of *Arrhinomyia tragica*. From the *Ephialtes* larvae there emerged 19 adults ; and from two cocoons there emerged Chalcids, believed to be *Perilampus* sp., which escaped.

(ix). *Department* : MEURTHE-ET-MOSELLE.

A collection was made at Toul from 16th to 21st March 1930.

Mean temperatures : July 18·2°C. ; January 0·1°C. ; annual 9·0°C.

"The climate is continental. The vine is more important than the apple here, and apple trees (which are chiefly eating apples) are few."

The following emerged :—

- 83 *Cydia pomonella*, L.
- 1 *Trichomma enecator*, Rossi (0·95 per cent.).
- 15 *Pristomerus vulnerator*, Panz. (14·29 per cent.).
- 6 *Ascogaster quadridentatus*, Wesm. (5·71 per cent.).

With 200 Codling Moth larvae, there were collected 10 cocoons of *Ephialtes extensor* and 2 cocoons of *Cryptus sexannulatus*, Gr. From the *Ephialtes* cocoons, 7 *Ephialtes* and 2 *Hemiteles hemipterus*, F., emerged. From the *Cryptus* cocoons, 2 adults emerged.

(x). *Department*: HAUTE SAVOIE.

A collection was made at Annecy from 25th to 27th March 1930.

Mean temperatures: July 19.7°C.; January 0.4°C.; annual 9.7°C.

"The climate is severe in winter, but very pleasant in summer. Hail is very frequent, and does much damage to crops. Orchards are fairly numerous, but scattered. The trees are young, vigorous, and very carefully looked after."

The following emerged:—

103 *Cydia pomonella*, L.

1 *Pristomerus vulnerator*, Panz. (0.93 per cent.).

3 *Ascogaster quadridentatus*, Wsm. (2.80 per cent.).

With 200 Codling Moth larvae, there were collected 4 cocoons of *Ephialtes extensor*, from which 3 adults emerged; 1 cocoon from which *Microcryptus abdominator*, Gr., emerged; and one cocoon containing an individual which died as a pupa, and which was believed to be *Cryptus* sp., possibly *C. sexannulatus*, Gr.

(xi). *Department*: ALPES MARITIMES.

Collections of parasites were made in the neighbourhood of Antibes, but as only parasite cocoons were received at the Laboratory, no percentages of parasitism are available. The following parasites emerged:—

Ascogaster quadridentatus, Wesm.

Pristomerus vulnerator, Panz.

Spilocryptus incubitor, Ström.

(xii). *Summary of Percentages of Parasitism.*

Locality	Year	<i>Pristomerus vulnerator</i> , Panz.	<i>Trichomma eneator</i> , Rossi	<i>Ascogaster quadridentatus</i> , Wsm.	<i>Ephialtes extensor</i> , Tasch.	<i>Arrhinomyia tragica</i> , Mg.
		%	%	%	%	%
Paris region (S. et O.) ...	1928-29	0.23	0.23	0.91		0.00
	1929-30	0.38	0.00	1.15	1.6	1.15
Elbeuf (S. Inf.) ...	1929-30	0.04	0.68	0.42	0.9	1.63
Lyons region (Rhône) ...	1929-30	0.39	3.11	0.39	11.0	0.39
Blois and Chaumont (I. et C.) ...	1928-29	11.00	2.00	1.00		1.00
Rennes (I. et V.) ...	1928-29	2.75	0.92	0.92		0.00
	1929-30	0.00	0.00	1.31	3.5	2.63
Beauvais (Oise) ...	1928-29	1.14	2.27	1.14		0.00
Brive (Corrèze) ...	1929-30	1.12	0.00	3.37	5.00	1.12
St. Pierre-sur-Dives (Cal- vados) ...	1929-30	3.57	1.19	2.38	4.85	1.19
Toul (M. et M.) ...	1929-30	14.29	0.95	5.71	4.76	0.00
Annecy (Haute Savoie)	1929-30	0.93	0.00	2.80	2.00	0.00

The absence of a percentage in the last column but one of the above table does not indicate necessarily the absence of *Ephialtes* from the locality concerned, but that no ectoparasites of *Cydia* were collected there.

5. Notes on Parasites reared.

Below is the complete list of parasites reared from the collections; only those marked thus—"P"—are definitely known to be primary parasites of *Cydia pomonella*, L.

ICHNEUMONIDAE :

- P *Pristomerus vulnerator*, Panz.
- P *Trichomma enecator*, Rossi
- P *Ephialtes extensor*, Tasch.
- Hemiteles hemipterus*, F.
- H. macrurus*, Ths.
- P *Cryptus sexannulatus*, Grav.
- Microcryptus abductor*, Grav.
- P *Spilocryptus incubitor*, Ström.

BRACONIDAE :

- P *Ascogaster quadridentatus*, Wesm.
- Meteorus chrysophthalmus*, Nees
- Dacnusa* sp.

CHALCIDIDAE :

- Perilampus tristis*, Mayr
- P. laevifrons*, Dalm.
- Monodontomerus dentipes*, Boh.
- P *Eurytoma appendigaster*, Boh.
- Eupelmus urozonus*, Dalm.
- P *Dibrachys cavus*, Wlk.
- P *D. affinis*, Masi

TACHINIDAE :

- P *Arrhinomyia tragica*, Mg.
- Exorista westermanni*, Zett.

(i) *Pristomerus vulnerator*, Panz. (Ichneumonidae : subfam. Ophioninae).

This species has been recorded from the following hosts :—

Lepidoptera :

- Aegeria vespiiformis*, L. (Aegeriidae) (Morley, 1914).
- Acrobasis porphyrella*, Dup. (Phycitidae) (Morley, 1914).
- Argyroplote (Olethreutes) variegana*, Hb. (Tortricidae) (Sarrazin, 1918).
- Argyrotoxa (Tortrix) bergmanniana*, L. (Tortricidae) (Morley, 1914).
- Cydia molesta*, Busck (Tortricidae) (Marlatt, 1931).
- C. pomonella*, L. (Tortricidae) (Feytaud, 1918).
- Dendrolimus pini*, L. (Lasiocampidae) (Sitowski, 1928).
- Depressaria nervosella*, Haw. (Oecophoridae) (Morley, 1914).
- Etiella zinckenella*, Tr. (Pyralidae) (Shchegolev & Mamonov, 1929).
- Eucosma ocellana*, F. (Tortricidae) (Woroniecka, 1926).
- Gypsonoma neglectana*, Dup. (Tortricidae) (Schütze & Roman, 1931).
- Platyedra gossypiella*, Saund. (Tineidae) (Kanbe, 1931).
- Poritethria dispar*, L. (Lymantriidae) (Meier, 1927).
- Pyrausta nubilalis*, Hb. (Pyralidae) (Goidanich, 1931).
- Rhyacionia buoliana*, Schiff. (Tortricidae) (Feytaud, 1921).
- Stenolechia albiceps*, Z. (Gelechiidae) (Faure, 1925).

Diptera :

Anthomyia albimana, Zett. (ANTHOMYIIDAE) (Morley, 1914).*Coenosia* sp. (ANTHOMYIIDAE) (Morley, 1914).

In addition, *P. vulnerator* has been reared at the Farnham House Laboratory from larvae of *Anarsia lineatella*, Zell. (Lep. GELECHIIDAE), collected on the French Riviera. Morley (1914) and de Dalla Torre (1898-1902) state that the species occurs throughout Europe. References have been found in the literature to its occurrence in England, France, Germany, Holland, Italy, Poland, Jugoslavia, Russia, Cyprus, Japan and Korea.

The following data refer to the emergence of *Pristomerus* from those of the collections made in France in 1928-29 and 1929-30 that were kept in the unheated outdoor insectary :—

June 1929														July								
	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	1	2	3	4	5
♂ emerged ...	1	1		5	1				1											3	1	
♀ emerged ...					1							1										

In 1929, the first *Cydia pomonella* emerged on 29th May, and the last on the 1st August, with the peak of emergence on 19th June.

	June 1930																				
	7-10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
♂ emerged	3	1	1	1		2	2	3	2												
♀ emerged				2		2		2	1	1	1						1	1			1

July 1930

	1	2	3	4
♂ emerged				
♀ emerged	1			

The emergence of *Cydia pomonella* started on 5th June 1930, reached a maximum about 21st June, and ceased on 11th August. Thus, it appears that male *Pristomerus* emerge slightly earlier than the females, and that the females have emerged by the time that any considerable number of Codling Moths have appeared. In addition to the emergences recorded in the above table, 7 males and 1 female *Pristomerus* emerged in 1930 from collections kept under different conditions. In both 1929 and 1930, males were more numerous than females in the collections, 9 males and 6 females in 1929, and 22 males and 14 females in 1930. The numbers concerned are small, however ; for purposes of comparison it may be interesting to record that from collections of *Cydia molesta* made by the laboratory in 1931, in the south of France, 13 males and 24 females were reared.

All adults were supplied with sugar, raisins, and water. Mating was not observed, but in the figures given below for length of life, individuals which had had opportunity to mate are separated from those definitely known to be unmated.

Length of life in days, at room temperatures										Average no. of days		
♂ unmated	...	23	0	2	49	51	54	25	46	16	...	29.6
Mated ?	...	16	49	46			...	...	...		...	37.0
♀ unmated	...	2	53	...	...	...	...	...	...		...	27.5
Mated ?	...	92	39	37	29	...	...	...	...		...	49.25

The apparent greater length of life of individuals which had had opportunity to mate disappears if the unmated males which lived 0 and 2 days, and the unmated female which lived 2 days, are omitted from consideration.

An attempt was made to breed *Pristomerus* in the laboratory, since it was too rare in France to make it possible to collect sufficient of the species for shipment. Very little success had been obtained by the time when it became necessary to cease work on the parasites of the Codling Moth, but certain facts regarding the life-history of the species were discovered. Apples were hung by their stalks from wires in cages containing *Pristomerus* females. Codling Moth eggs about to hatch were put on the apples; the newly emerged larvae from these eggs entered the apples, usually choosing for an entrance a spot on the side of the apples, which were full-grown. Codling Moth larvae, after entering the apple, spend some time immediately under the point of entrance, covering the hole with a web, and depositing on this web bitten-off pieces of apple. Frequently, also, the larva makes a semi-circular tunnel immediately under the skin of the apple before going deeper into the flesh. On many occasions *Pristomerus* females were seen with their ovipositors inserted into the apple, apparently in the act of oviposition. The female moves the ovipositor in and out in various directions through the flesh of the apple with the greatest ease. Codling Moth larvae in these apples were found to contain parasite eggs; in one case, however, as many as five parasite eggs were laid in a newly-hatched host larva, and the larva was killed, its body being filled with eggs. One host caterpillar, dissected 18-20 days after stinging, was found to contain a parasite egg, from which a larva was just emerging.

The life-history of *Pristomerus* as a parasite of the Codling Moth may then be summarised as follows:—Adults emerge in the early summer, slightly before the emergence of the bulk of the host; the females oviposit in Codling Moth caterpillars immediately after the latter have entered the apples, and the parasites live, in the egg and first larval stages, in their hosts during the period spent in the apple. The caterpillar then leaves the apple and makes its cocoon. The parasite passes the winter inside its host, emerging in the spring and spinning its cocoon inside that of its host. According to Goidanich (1931), there are two generations a year in Italy.

The egg of *P. vulnerator* is light brown in colour, the ends of the egg being paler and more transparent. Hatched eggs dissected from the body of the host are much darker in colour than are the newly laid eggs, and do not show the lighter areas. The surface of the egg is not sculptured. The egg is strongly curved in the middle of its length, and is narrower at the caudal than at the cephalic end. The difference between the two poles of the egg is shown in fig. 2 A. The caudal end of the egg is evenly rounded; while at the cephalic end, that half of the pole of the egg which is towards the inside of the curvature of the egg is blunter and has a smaller radius of curvature than that half of the pole which is outside. Eggs are from 0.24 to 0.28 mm. in length, and from 0.05 to 0.06 mm. in greatest width. The widest part of the egg was found to be sometimes at the curve of the egg, and sometimes between the curve and the cephalic end. There is considerable variation in the proportions of the eggs, there being no constant ratio, either direct or inverse, between length and width.

The first stage larva is of the typical internally-feeding Ichneumonid type, with strongly sclerotized head, and a body ending in a long tail; the larva is somewhat longer than the egg, as the tail is folded under the abdomen prior to eclosion. The golden-brown head-capsule bears two sharply curved, pointed mandibles, which are without lateral teeth. The head-capsule is flattened ventrally, and there are distinct ridges between this ventral portion and the lateral regions of the head. At the anterior ends of these ridges are articulations for the mandibles; each mandible has another articulation with a rounded boss situated anterior to the mandible, on the edge of the oral cavity. On the ventral surface of the head there are two longitudinal rows, each of three small setae; there are a few other setae on the lateral areas of the head-capsule.

The head of the mature larva has been figured by Goidanich (1931), but his figure is not in complete agreement with the specimens examined by the present writer.

The chitinous structures of the head are very similar to those of the Ophionines, *Omorgus* and *Eulimneria*, figured by Thorpe (1930). Thorpe's nomenclature will be adopted here. The mandibles articulate with the somewhat ill-defined labral struts and the mandibular struts. The maxillary strut is well developed and reaches to the labial strut, which lies very close to the labial ring; in Goidanich's figure, these three structures appear to fuse, which is not the case. The labial ring is not complete, its outline becoming very vague near the median line. The main sense-organs present around the mouth are three pairs of sensoria. Of these, the labial and maxillary sensoria each consist of two papillae surrounded by a sclerotized area; but the labral

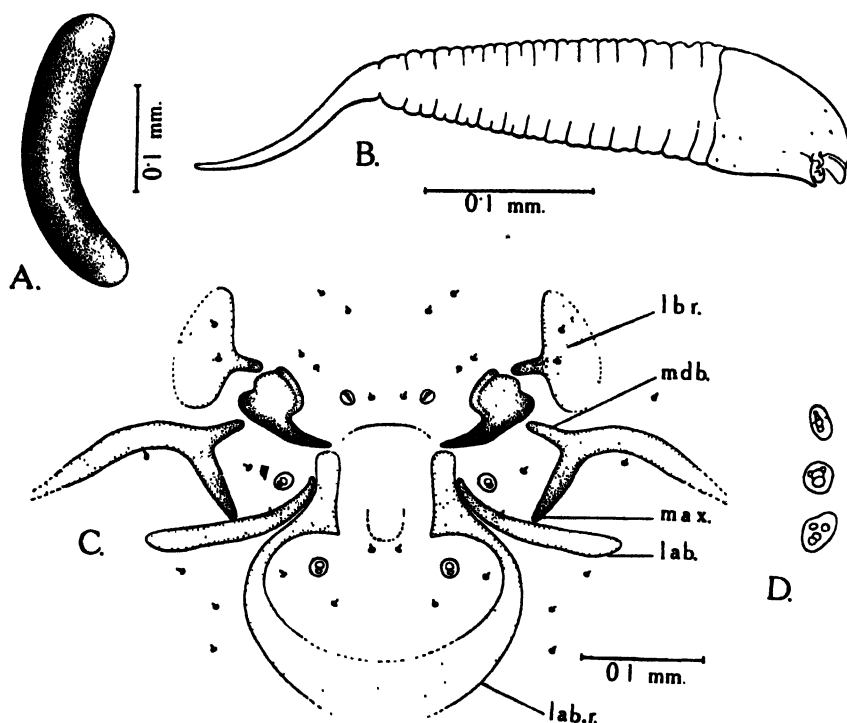


Fig. 2. *Pristomerus vulnerator*, Panz.: A, egg; B, 1st stage larva; C, facial rods and mouth-parts of mature larva; D, labral sensoria of three mature larvae; *lbr.*, labral (frontal) strut; *mdb.*, mandibular strut; *max.*, maxillary strut; *lab.*, labial strut; *lab.r.*, labial ring. (Note—The 1st stage larva shown is newly hatched; older larvae of this stage have a tail equal in length to three-quarters of the body.)

sensoria each bear four papillae, and not two as Goidanich shows. Of these papillae, two are large, and two smaller; there was considerable variation in the specimens examined in the arrangement of the papillae; examples are shown in fig. 2D. The following areas of the head are slightly sclerotized, their boundaries being ill-defined: the labral region, the region between the ends of the mandibular strut and the labral strut, and a Y-shaped patch in the labial area, between the sensillae; this last area is only very lightly sclerotized in this species. The various small setae round the mouth-parts were found to agree well in position with those shown by Goidanich; in some specimens extra setae were found to be present.

(ii). *Trichomma enecator*, Rossi (Ichneumonidae; subfam. Ophioninae).

This species has been recorded from the following hosts:—

Lepidoptera: *Acrobasis consociella*, Hb. (PYRALIDAE) (Morley, vol. v, 1914).

A. porphyrella, Dup. (PYRALIDAE) (Morley, t.c.).

Cacoecia decretana, Treits. (TORTRICIDAE) (Morley, t.c.).

Cydia cynosbana, F. (TORTRICIDAE) (Wagner, 1928).

C. molesta, Busck (TORTRICIDAE) (Allen, 1932).

C. pomonella, L. (TORTRICIDAE) (Faure, 1925).

Earias chlorana, L. (NOCTUIDAE) (Morley, t.c.).

Ectropis bistortata, Goeze (GEOMETRIDAE) (Morley & Rait-Smith, 1933).

Eucosma (Phloeodes) tetraquetra, Haw. (EUCOSMIDAE) (Morley, t.c.).

Gelechia boticella (GELECHIIDAE) (Habermehl, 1922).

Pachythelia (Psyche) villosella, Ochs. (PSYCHIDAE) (Morley, t.c.).

Peronea hastiana, L. (TORTRICIDAE) (Morley, t.c.).

Porthetria (Lymantria) dispar, L. (LYMANTRIIDAE) (Morley, t.c.).

Sparganothis (Tortrix) pilleriana, Schiff. (TORTRICIDAE) (Habermehl, 1922).

Tortrix lauffauriana, Reg. (TORTRICIDAE) (Silvestri, 1923).

T. loeflingiana, L. (TORTRICIDAE) (Silvestri, 1923).

T. viridana, L. (TORTRICIDAE) (Silvestri, 1923).

Morley (v, 1914, p. 234) further records *T. enecator* as having been reared from "*M. fenestrata*"; and, according to Schmiedeknecht (1908-11, iv, p. 1468), Krieger reared this species from a tortrix on blackberry. Schmiedeknecht says that *T. enecator* occurs over a large part of Europe, but is not abundant. References have been found to its occurrence in England, Germany, Denmark, France and Italy.

Date of emergences from French collections in unheated outdoor insectary:—

		May 1929							June 1929		
		25	26	27	28	29	30	31	1	2	3
♂ emerged	...	1		1							
♀ emerged	...	1		1				1		1	

Cydia emergence: 1st moth—29th May; peak of emergence—19th June; last moth—1st August.

		May 1930														June 1930									
		14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	1	2	3	4	5	6
♂ emerged	1			2					1							3	1			1		1			
♀ emerged						3				1					1					1				2	

Cydia emergence: 1st moth—5th June; peak of emergence—21st June; last moth—11th August.

Thus, *T. enecator* emerges some weeks before its host, *C. pomonella*. In addition to those mentioned above, 3 males and 1 female emerged in 1930, making totals of 2 males and 4 females in 1929, and 13 males and 9 females in 1930. The only reference found to the relative abundance of the sexes is that of Morley (1914, p. 234), who mentions a collection of 14 specimens, only 3 of which were males, bred from *Cacoecia (Tortrix) decretana*. Morley gives several records of the capture of the adult insect in Britain on various dates in June.

Length of life in days, at room temperatures		Average
		(days)
Male ...	33, 34, 20, 11, 20, 35, 9, 20...	24.0
Female ...	15, 38, 7, 11, 41, 42 ...	25.6

The lengthy period between the emergence of the parasite and host is noteworthy; but as in captivity both sexes may live a month or more, *T. enecator* may yet parasitise the progeny of the corresponding generation of moths, as the latter commence to oviposit one or two days after emergence, their eggs hatching in about eight days.

Further, one pair of parasites was observed to copulate 10 days after emergence. If this delay prior to mating is normal, it is in accordance with the early emergence of the host, and precludes any possibility of the parasite passing through a generation on another host before parasitising *C. pomonella*. In the case observed, the copulating insects were clinging to the gauze side of the cage, head upwards, and the female vertically above and in front of the male. The abdomen of the female was held straight out, with the ovipositor slightly raised. The head of the male was behind the tip of the abdomen of the female, the distance between them being roughly equal

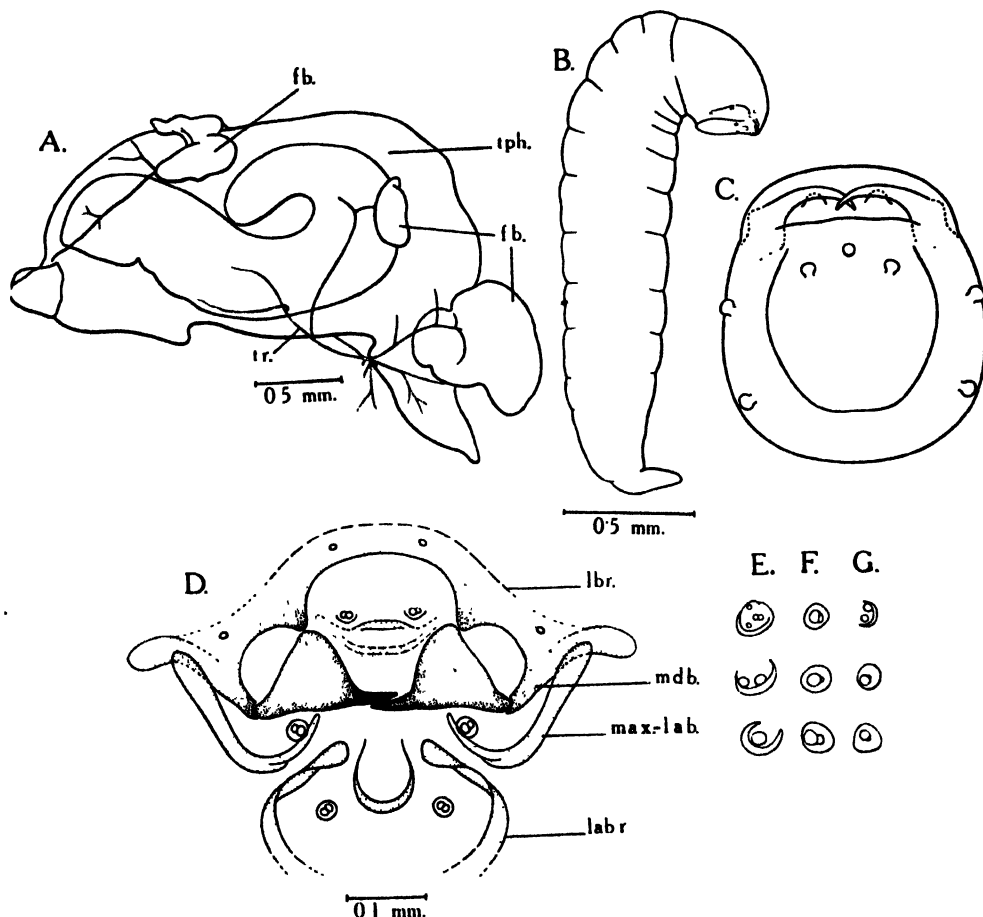


Fig. 3. *Trichomma enecator*, Rossi: A, young larva in trophamnion; B, young larva; C, head of young larva; D, mouth-parts and facial rods of mature larva; E, G, labral, maxillary and labial sensoria of the left side of one individual, and F, G, the same of two other individuals; *tph*, trophamnion; *fb*, fat-body of host; *tr*, tracheae of host; *max-lab*, maxillary-labial strut; *mdb*, mandibular strut; *lbr*, labral strut; *lab.r*, labial ring.

to the length of the thorax. The abdomen of the male was curved under its head. When first observed the insects were in the act of copulation, so no courting was seen.

Attempts were made to breed *T. enecator* in the laboratory, but no success whatever was obtained. The females would not sting the host larvae in any stage, and showed no interest in them. Judging from the size of the ovipositor, it seems probable that the species oviposits in the young larva soon after it has entered the apple, as does *Pristomerus vulnerator*; the ovipositor appears too small for successful

oviposition in host larvae in cocoons in crevices of the bark, and much too large for oviposition in eggs. Certainly it cannot oviposit in the pupa, since all the material obtained was from collections of host larvae. Morley states that *T. enecator* emerges from the chrysalis of its host, making no cocoon of its own; but a very thin and fragile cocoon is woven inside the host pupa. The parasite emerges from the head end of the host pupa by biting along a fairly regular line round the pupa, passing through the middle of the thorax.

Two young larvae, believed to be *T. enecator*, were obtained by dissection of hibernating Codling Moth larvae. Each was within a gelatinous cyst or trophamnion, approximately 2.5 mm. in length by 1.25 mm. in breadth, but irregular in shape. The trophamnion was translucent, and the larva could be observed within it, lying with the tip of the abdomen curled up. The trophamnion was closely attached to various portions of the fat-body of the host, and to its tracheae; apparently the trophamnion becomes fastened to those parts of its host that it touches during the growth of the larva. In this way the host's tracheae come to lie along the wall of the trophamnion. The larva in both cases had a slightly sclerotized head and a small tail; they were probably in the second stage. The dorsal and lateral parts of the head are covered by a large shield. The long mandibles are situated antero-ventrally; from them the flat clypeal and labral regions slope away, as two plane surfaces. On the labral region is a prominent U-shaped ridge, which forms the outline of the head when seen from the side. There are three pairs of sense-organs on the labial region of the face, each of which is in the form of a sphere, with a wide stalk. Of these, the anterior pair are smaller than those of the other two pairs, and are situated within the U-shaped ridge, posterior to the opening of the salivary duct; the second pair are outside the ridge. In one specimen the third and posterior pair are also outside the ridge, but in the other specimen the ridge is much wider in this region, and the sense-organs are on or slightly within in. Anterior to the mandibles are a pair of nipple-shaped papillae. The cuticle is slightly sclerotized round the opening of the salivary duct.

The head structures of the mature larva were examined in cast skins only. The labral struts form a large sclerotized semi-circular ring, with its outer edge less well-defined than its inner edge. The mandibular struts are fused with the labral struts. Both the labral and mandibular struts bear condyles for the articulation of the mandibles, which are somewhat bluntly pointed, and are without teeth. There is some difficulty in homologising the structures present with those described as maxillary struts and labial struts by Thorpe (1930) and Salt (1931). In the species of Ichneumonids and Braconids examined by these authors, the maxillary strut is continuous with, or is a small outgrowth of, the mandibular strut, while the labial strut is separate and distinct. In *T. enecator* there is a single curved strut (see fig. 3D, maxillary-labial strut) which appears to consist of two parts fused. One end of this strut lies exterior to the mandibular strut; the end of the strut is broad and solid. In the middle of the strut the broad structure is joined by a much lighter strut, which runs forward towards the mouth. The stout structure apparently represents the maxillary strut, which is not attached to the mandibular strut, but is fused with the much lighter labial strut. The labial ring is incomplete, and consists of two curved and folded, ribbon-like sclerotized structures. Within the labial ring is another sclerotized ring, complete ventrally, surrounding the hypopharyngeal area; this structure may be termed the hypopharyngeal ring. The cuticle of the face region is mostly unsclerotized, and is raised in numerous papillae, which are so numerous within the hypopharyngeal ring and between it and the oral opening, as to give the cuticle a reticulate appearance. Across the clypeus, the cuticle is sclerotized in a curve shaped like a broad W; between the curve and the mouth is a slightly sclerotized area, which is somewhat ill-defined, but reaches to the extremities of the W-curve. Three pairs of sensorial structures are present, labral, maxillary, and labial; these are very variable in structure. In most cases, each sense-organ consists of a sclerotized papilla, bearing

one or more sensillae; but there is a tendency for the papillae to be sclerotized on one side only, giving it a semi-lunar appearance, while the sensillae vary in size and numbers. In fig. 3 E, F and G are shown the labral, maxillary and labial sensoria of the left side, of three individuals, illustrating this variation. Sensory hairs on the face are minute and variable. There are four small, oval, unsclerotized areas in the labral (or frontal) ring, two anteriorly, and two laterally. In one specimen, there were two of these anterior, unsclerotized areas on the right side of the ring, and only one on the left side; in some specimens, the anterior areas lie so far out on the frontal ring as to become indentations of its outer edge.

It would be most interesting to examine larvae of other species of the genus *Trichomma*, to observe if the structure here termed the maxillary-labial strut is of the same form, and has the same relation to the other structures of the head; and to observe if specific determination of the larvae is possible in view of the variation of the sense-organs observed in the species *enecator*.

(iii). **Ephialtes extensor**, Tasch. (Ichneumonidae: subfam. Pimplinae).

This species has been recorded from the following hosts :—

Lepidoptera :

Cydia pomonella, L. (TORTRICIDAE) (Wilkinson, 1926).

Monopsis rusticella, Hl. ? (TINEIDAE) (Seyrig, 1924).

Coleoptera :

Saperda populnea, L. (LAMIIDAE) (Scheidter, 1917).

The following have also been recorded as parasites of *C. pomonella* :—

Ephialtes aequalis, Prov. (Cushman, 1920).

E. carbonarius, Christ (Feytaud, 1918).

E. sanguineipes, Cress. (Cushman, 1920).

Calliephialtes messor, Grav. (Lounsbury & Faure, 1918).

C. nucicolor, Cushm. (Barrett, 1932).

In view of the systematic difficulty of separating the two genera into species, it seems possible that some of these records really refer to *E. extensor*, and also that the host list of *E. extensor* should be larger than it is at present. There has been considerable doubt as to the identity of parasites of the Codling Moth belonging to these genera, and in at least one paper, such a parasite has been referred to as the "Spanish Codling Moth parasite," without any scientific name being given. Specimens from the collections made in France have been determined by Dr. Ch. Ferrière as *E. extensor*, Tasch. This determination was confirmed by Dr. A. Roman of Stockholm; the following information was given by him, *in litteris*: "The *Ephialtes* you sent me for naming is a race of *E. extensor*, Tasch., the ♀ differing from the typical species by its almost transverse 1st abdominal segment. The ♂, however, is typical *extensor*. In U.S.A. *extensor* has been bred from the same host under the name of '*Calliephialtes pusio*' (Walsh) Ashm., but the female has a typical 1st abdominal segment and the abdomen more shining, remoter punctured. The ♂ of this one, too, is typical *extensor* (I have a pair from Ashmead)." The geographical distribution of the species is given by Schmiedeknecht (1906-08, iii, p. 1134) as Germany and Sweden; Seyrig (1924) mentions the Swiss Jura and the Thann Valley; it has also been recorded from Cyprus and Russia.

Dates of emergence from French collections in unheated outdoor insectary :—

May 1930

	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
♂ emerged :																									
	3	1			2		1					2	3	1	1	1	1								
♀ emerged :																									
	1				3			2	3	2											1	2	4	5	4

June 1930											
	1	2	3	4	5	6	7	8	9	10	11
♂ emerged	...										
♀ emerged	...	2	3	5	4	1			1	1	

Cydia emergence: 1st moth—5th June; peak of emergence—21st June; last moth—11th August.

In addition to the individuals mentioned above, 17 males and 49 females emerged in the laboratory, making a total of 33 males and 93 females. The *Ephialtes* females thus emerge three weeks or a month before the *Cydia* adults; this point will be discussed after some details of the biology of the parasite have been given.

Length of life in days										Average (days)
A. At room temperatures										
Male	...	30, 17, 53, 43, 40, 33, 57, 42, 52, 14, 21	...	...	...	...	...	...	...	36.5
Female	...	36, 65, 54, 87, 75, 17, 25, 12, 65, 39, 46, 53, 75, 41, 95, 37, 49, 56, 62, 75, 70	...	...	...	...	...	...	...	53.9

B. In unheated outdoor insectary (mean temperature approximately 60°F.)

Length of life in days										Average (days)
Male	...	27, 46, 50, 8, 47, 50, 46, 49, 50, 43, 30, 53	...	...	...	...	...	...	...	41.6
Female	...	4, 32, 45, 42, 58, 66, 6, 58, 72	...	...	...	...	...	...	...	42.6

C. At 25°C.

Male	...	52								
Female	...	13, 23, 27, 28, 27, 2, 51, 26, 28	...	...	...	...	...	...	...	25.0

All adults were supplied with water, raisins and sugar throughout life. The *Ephialtes* mated readily in captivity, but no significant difference in length of life was observed between unmated and mated individuals. The length of life of females at 25°C. is noticeably shorter than at lower temperatures; females which were kept at lower temperatures for a time before being transferred to hot conditions withstood the high temperatures better than those which emerged and passed their whole lives at 25°C., as the following individual cases show:—

Initial temperature	Days	Subsequent temperature	Days	Total life
Room temperature	37	25°C.	14	51
" "	24	"	58	82
" "	38	"	13	51
" "	21	"	>20	>41
Outdoor temperature (mean approx. 60°)	59	"	26	85
" "	54	"	2	56
" "	54	"	6	60
" "	54	"	26	80
" "	60	"	17	77
" "	60	"	31	91

When collections of *Cydia* larvae were made in autumn, immature larvae and eggs of *Ephialtes* were found in the cocoons of paralysed larvae; at Elbeuf in the first half of September 1929, most of the *Ephialtes* larvae had not completed their development. As the season advances, the larvae finish feeding and spin a cocoon, in most cases completing this by the beginning of October. Two larvae which had not yet made their cocoons were found at St. Laurent-les-veaux, however, at the end of December 1929. The larvae pupate in the spring and adults emerge. In June 1930, *Ephialtes* females were found at St. Pierre-sur-Dives attacking overwintering Codling Moth larvae. The emergence records given above show that the first female *Ephialtes* emerge nearly a month before the first moths; and figures given by Glenn, 1922, Selkregg and Siegler, 1928, and Van Leeuwen, 1929, show that under differing climatic conditions prevailing in Illinois, Delaware, and North Georgia, some of the hibernating *Cydia* larvae do not pupate until at least one month after the emergence of the first moths. Now, it was found in the laboratory that there was a period of 20–30 days between the emergence of the *Ephialtes* female and its first oviposition, when kept at room temperature, and in the cooler, outdoor conditions of May, this period possibly is lengthened. Thus it appears probable that at least half the caterpillars have pupated before any *Ephialtes* are ready to oviposit, but nevertheless, there is a large host population of hibernated larvae still available when the earliest *Ephialtes* females commence egg-laying. At this point it may be mentioned that the stinging of larvae, causing paralysis and eventual death, may take place some days before the parasites oviposit. When the majority of the females are ready to commence oviposition, at from the middle to the end of July, few or no overwintered hosts are available, but larvae of the first brood are by this time commencing to leave the apples and make their cocoons. One male and two female *Ephialtes* were reared by the end of July 1930, from eggs laid by females emerged in the spring on hibernated Codling Moth larvae, these eggs with their hosts having been collected in June 1930. Such adults would be ready to oviposit in late first-brood larvae. Thus there is a rather confusing overlapping of generations of hosts and parasites and the situation may be summarised as follows:—

<i>Parasite adults</i>		<i>Host larvae</i>
In autumn, last summer brood, 1929 ...	attack	Hibernated larvae, 1929–30
In spring, spring brood, 1930 ...	attack	First brood larvae, 1930
(hibernated as larvae)		
First brood, 1930 ...	attack	

The number of broods a year was not determined; but as the life of adults may be nearly three months, evidently the progeny of any one female may differ considerably in this respect. In California there are stated to be 5–7 broods of "*Calliephialtes*" each year (Smith & Vosler, 1914).

Ephialtes adults copulate readily in captivity; mating has been frequently observed in adults kept in dull places, and adults which have emerged and been kept continuously in artificial light mate and breed successfully. In mating, the male mounts the female and curves his abdomen round one side of the ovipositor, usually the left side. The antennae of the female are held vertically and almost motionless, those of the male almost horizontal and continuously vibrating. The act of copulation lasts three or four minutes, the female usually terminating the act by jerking the abdomen and throwing the male. Mating has not been observed prior to three weeks after the emergence of the female, at outdoor temperature.

Period between emergence of females and first oviposition, in days:—

At 25°C.	...	...	...	19, 16, 17
At 17–18°C.	...	...	...	22
At room temperature	...	...	...	33, 22, 28

As the above figures show, a considerable period elapsed between emergence and the first oviposition by a female. (Cushman, 1913, speaking of a parasite which he was unable to name definitely, but which was probably *Ephialtes extensor*, Tasch., since it was a Codling Moth parasite of the genus *Ephialtes* or *Calliephialtes* introduced into America from Spain, mentions a pre-oviposition period of about nine days.) Females which were supplied with host larvae from the time of emergence onwards showed interest in the larvae and stung and paralysed them during a period of from 2 to 7 days before they oviposited.

Cydia larvae were supplied to the female parasite in their cocoons, made in sections of corrugated cardboard. Standing on the cardboard, the female raises its abdomen and lowers the ovipositor, the latter being gripped at its tip by the sheath. The tip of the ovipositor is brought to a point between the feet, and, held by the ends of the sheath, it rapidly bores through the cardboard and enters the cocoon. The abdomen is now curved down, the ovipositor going further into the cocoon, while the sheath returns to an almost vertical position making nearly a straight line with the ovipositor. The female jabs her ovipositor into the cocoon, locating and stinging the larva. When the larva has been stung the female may withdraw her ovipositor, or wait with it in the cocoon. A short time is spent in tapping the cocoon with the tips of her antennae; then, if it has been withdrawn the ovipositor is re-inserted; rhythmic movements take place in the abdomen, and an egg is laid. If few hosts are available, the female may return to the same cocoon immediately and lay a second egg without re-stinging the larva. The eggs are laid anywhere in the cocoon, and not necessarily on the larva. The larva is usually stung in several places prior to oviposition; it bleeds at the point of stinging, in some cases to such an extent that its body becomes shrunken and the congealed blood glues it to the cocoon. The parasite eggs are sometimes partly embedded in congealed blood. When the stinging has been slight, the body of the caterpillar appears healthy, the heart beats, and the only noticeable effects are the paralysis of the larva, and a brown ring which appears round the point of stinging. The female parasite frequently fed on the blood of the caterpillars.

Total number of eggs laid per female :—

Unmated	Life 82 days		Laid 68 eggs and 4 collapsed eggs
Unmated	Life 98 days		Laid 26 eggs
"	" 23 "	at room temperature	" 0 "
"	" 13 "	" "	" 0 "
Mated	Life 51 days	at room temperature	Laid 89 eggs and 18 collapsed eggs
"	" 80 "	" "	" 33 eggs and 7 collapsed eggs
"	" 95 "	" "	" 22 eggs
"	" 27 "	at 25°C.	" 34 eggs and 2 collapsed eggs
"	" 43 "	at 25°C.	" 0 eggs

In addition, two females were killed by ants during their oviposition period :—

Mated	Life 41 days	at 25°C.	Laid 111 eggs and 23 collapsed eggs
Unmated	" 49 "	at 25°C.	" 37 eggs and 2 collapsed eggs

Certain females laid eggs which consisted of a chorion with little or no contents; these are referred to above as "collapsed eggs." Such eggs were laid at any time during the oviposition period, but were especially numerous after a female had laid a large number of eggs in a short time. Normally a female lays from one to four eggs a day; the greatest number of perfect eggs laid by one female in a day is 12. A female which is ovipositing regularly will, if supplied with hosts, continue to do

so until she is too weak, through old age, to pierce the cocoon with her ovipositor ; she then walks feebly about the cage for some days and finally dies. Unmated females lay eggs from which males usually develop ; but from one parthenogenetic egg a female was reared. This somewhat unusual occurrence gives rise to the suspicion that a mistake had been made, and a fertilised egg substituted for an unfertilised one ; but it is difficult to see how this could have taken place, since each egg was kept in a separate tube, labelled and numbered.

After hatching, the larva feeds externally on the host. There are five larval instars. In the fifth stage, the larva pushes the now empty remains of the host to one end of its cocoon, and spins a cocoon, conforming in shape to the space remaining in that of the host. The larva then enters into the prepupal stage, pupates, and finally the imago emerges from the pupal skin, but spends a period of up to two days within the cocoon before biting its way out. The following figures give the length of each stage in the case of isolated individuals kept at a temperature of 25°C. Observations were taken once daily.

	Male	Female
Incubation period	1.07 days (13, 1, 2)	1.3 days (3, 1, 2)
1st stage	1 (2, 1, 1)	1 (1)
2nd stage	1 (1)	—
3rd stage	1.6 (3, 1, 2)	—
4th stage	1 (3, 1, 1)	—
5th stage to commencement of cocoon	1.2 (5, 1, 2)	—
Period occupied in spinning ...	2.3 (9, 1, 4)	3 (1)
Period from completion of cocoon to assumption of prepupal form	3.2 (5, 2, 4)	4 (1)
Prepupal period	2.2 (10, 1, 5)	2 (5, 2, 2)
Pupal period (including time spent by emerged adult in cocoon) ...	6.6 (11, 5, 8)	7 (4, 6, 9)
Period from oviposition to emergence of adult	20.6 (28, 17, 26)	21.8 (6, 20, 23)

The periods shown above are averages ; the figures given in brackets are first, the number of individuals observed, and, second and third, the minimum and maximum number of days observed for each period. As shown above, the maximum incubation period for eggs which gave rise to adults that completed their development was two days ; one egg hatched three days after oviposition, but in this case the larva died shortly after eclosion.

Thus, at 25°C., approximately three weeks elapse between oviposition and emergence of adult, and, as stated previously, there is a period of adult life of from 10 to 19 days at this temperature before the female commences to oviposit. Under outdoor conditions of lower temperature, these times would be considerably increased. It may be noted that at Farnham Royal the mean monthly temperatures for June, July and August are 15°C., 16.6°C. and 16.1°C. respectively.

The newly-laid egg of a young female *E. extensor* is elongate, curved, rounded at the cephalic end, and more pointed at the caudal end. The ends are clear and translucent, the middle is opaque white. The egg is approximately 1.75 mm. long, by 0.35 mm. in its greatest width. The surface of the egg is raised in low, rounded bosses, which are set close together, and arranged in lines running diagonally round the egg ; the arrangement of the bosses becomes less distinct towards the cephalic end of the egg. Towards the caudal end the bosses become arranged in longitudinal rows, with faint longitudinal lines between them ; as the caudal end of the egg is approached, the bosses become less distinct and the lines more distinct. The bosses are absent on the clear portion of the caudal end, while the lines continue to the

pole. When development of the egg has commenced, the contents shrink, and portions of the chorion at both ends of the egg become flattened. Eggs laid later in the life of a female are of a different shape; they are less elongate, and broader, as shown in fig. 4. The clear portions of the egg are smaller, especially at the cephalic end, and a smaller part, or even none, of the egg becomes flattened during development. This alteration of shape of the egg was observed in all the females used in the breeding work. Eggs which are extremely short may hatch; but some evidence was obtained indicating a lower viability in these eggs. For instance, in the case of a female which laid 68 eggs, of the first 16 eggs laid, all of which were more or less of the elongate type, only one failed to hatch; of the last 16 laid, all of which were markedly less elongate, three did not hatch.

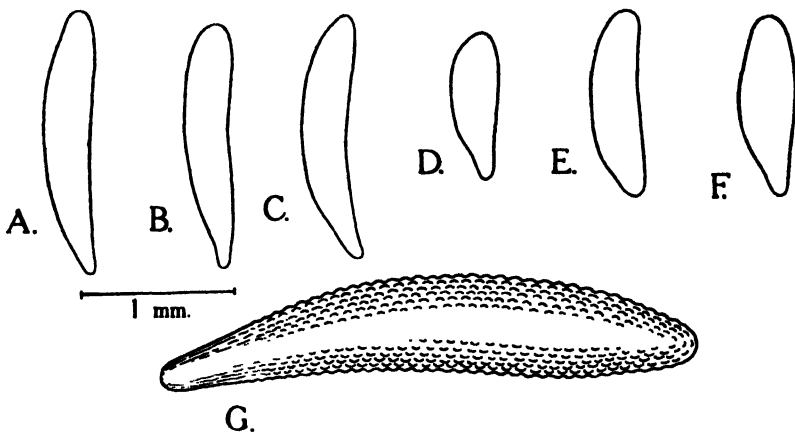


Fig. 4. *Ephialtes extensor*, Tasch., egg: A, B, C, D, E and F, the 1st, 3rd, 5th, 60th, 66th and 67th egg respectively, laid by one female; G, enlarged view of egg.

The newly hatched larva is from 0.9 to 1.05 mm. in length, and approximately 0.35 mm. in width. The large, blunt head is lightly sclerotized; the body is almost parallel-sided up to a point one-quarter of the larva's length from the caudal end, from which point it rapidly decreases in breadth. There are 13 body segments. The cuticle is covered with minute, close-set papillae, and bears numerous setae, approximately 0.02 mm. in length, on both dorsal and ventral surfaces. The only highly sclerotized parts of the head-capsule are the mandibles, which are elongate, curved, and unserrated. The labral area is enclosed by a narrow, slightly sclerotized ring, at the ends of which lie the small labral struts. A second point of articulation for the mandibles is provided by the mandibular struts; these are sharply defined for a short distance only, but continue down towards the cervical region as very slightly sclerotized structures. There is a slightly sclerotized connection between the labral and mandibular struts. The labial ring is an indistinct structure; on either side of it are folds or thickenings of the cuticle, which together form a V. The antennae, which are in the form of papillae, are on the dorsal surface of the head. Various sensory hairs are present, including two pairs within the labial ring, two rows of four hairs each, outside the labial ring, a row of four on each side of the anterior part of the labral region, and an irregular row on each side of the mouth parts. Corresponding hairs to those mentioned can be found in all stages of the larva.

In the second stage, the larva becomes more fusiform. The facial rods and mouth-parts are very similar to those of the first stage, but the mandibles are serrated. In the third stage, the mandibular strut at its posterior end gives off a branch which moves towards the median line and anteriorly. This branch becomes more definite

in the fourth larval stage, but it remains very lightly sclerotized ; in this stage there is a group of papillae at the posterior end of the labial ring. In the last larval stage, the facial rods closely resemble those of *Pimpla detrita*, Hlmgr., as figured by Salt (1931). The parts are now highly sclerotized. The labial ring is a stout structure,

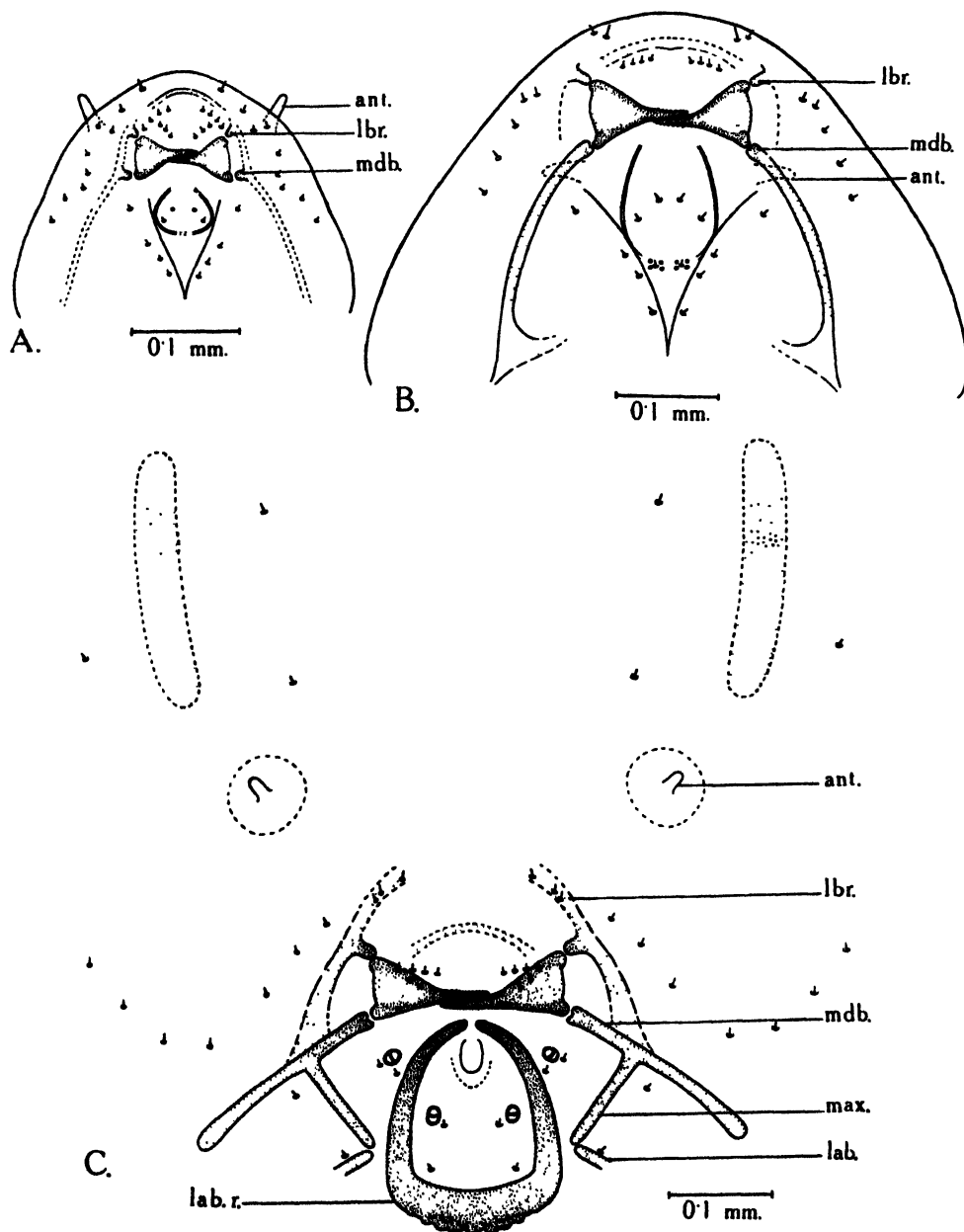


Fig. 5. *Ephialtes extensor*, Tasch. : A, B, and C, facial rods and mouth-parts of 1st, 4th and 5th stage larva respectively; *lbr.*, labral strut; *mdb.*, mandibular strut; *max.*, maxillary strut; *lab.*, labial strut; *lab. r.*, labial ring; *ant.*, antenna (showing by transparency from dorsal side of head in B).

with approximately 12 low, rounded bosses on its posterior face. The maxillary strut is a branch given off by the mandibular strut, and running to the posterior angle of the labial ring, which is also supported at this point by the labial strut. The labial strut is short, not reaching the posterior end of the mandibular strut, as is the case with *Pimpla detrita*. The opening of the salivary duct lies between the arms of the labial region. The clypeus is sclerotized; and below it, on the labrum, are six pairs of setae. The labral struts are small, but from them extend an indistinct and incomplete frontal ring, and an indistinct sclerotized area extending towards the junction of the mandibular and maxillary struts. There are, on either side, three setae, associated with the frontal ring. Anterior to the frontal ring are the antennae, which are situated in a circular, clear area of cuticle; they are sclerotized. Dorsally, and slightly lateral, to the antennae, and extending almost to the postero-dorsal margin of the head-capsule, are two elongate areas in which the cuticle is slightly sclerotized; these areas are not clearly defined. In the fifth stage larva, there appear, for the first time, the labial and maxillary sense-organs, of typical form. The cuticle of the whole head region bears low, rounded, close-set papillae, and numerous small setae; only the larger setae, which can be homologised with those of the earlier stages, are shown in fig. 5.

(iv). **Hemiteles hemipterus**, F. (Ichneumonidae: subfam. Cryptinae).

This parasite has been recorded from the following hosts:—

Lepidoptera :

- Euzophera cinerosella*, Zell. (PYRALIDAE) (Bignell, 1898).
- Clysia ambiguella*, Hübn. (PHALONIIDAE) (Schwangart, 1918).
- Polychrosis botrana*, Schiff. (EUCOSMIDAE) (Catoni, 1914).
- Laspeyresia microgrammana*, Guen. (EUCOSMIDAE) (Morley, vol. ii, 1907).

Coleoptera :

- Hypera variabilis*, Hbst. (*Phytonomus posticus*, Gyll.) (CURCULIONIDAE) (Cushman, 1927).

Hymenoptera :

- Cephus pygmaeus*, Linn. (CEPHIDAE) (Salt, 1931).
- Hyperparasite on *Pyrausta nubilalis*, Hübn., through *Eulimneria crassifemur*, Thoms. (ICHNEUMONIDAE) (Cushman, 1927, p. 12); *Microgaster globatus*, Spinola (BRACONIDAE) (Goidanich, 1931, p. 151); *M. tibialis*, Nees (BRACONIDAE) (Cushman, 1927, p. 12).
- Hyperparasitic on *Clysia ambiguella*, Hübn., through *Pimpla alternans*, Grav. (ICHNEUMONIDAE) (Schmiedeknecht, vol. ii, 1904–06) (Salt, 1931).
- Hyperparasitic on *Cephus pygmaeus*, Linn., through *Microbracon terebella*, Wesm. (BRACONIDAE) (Salt, 1931, p. 504).

The above list is copied, with additions, from that given by Salt (1931, p. 503). In addition, Salt records, as a hyperparasite on *Hemiteles hemipterus*, F., *H. inimicus*, Grav. The species has been recorded from Britain (Morley, 1907, p. 155) and North and Middle Europe (Schmiedeknecht, 1905, p. 870).

All individuals of this species emerged under artificially heated conditions, so no information as to the normal date of emergence was obtained. Of the specimens reared from the French collections, 7 were males and 5 females.

Length of life of individuals:—

At room temperature		At 25°C.	
Male	Unmated : 52 days	Male	Unmated : 23, 37 days
	Mated : 67 days		Mated : 70 days
Female	Unmated : 31, 59, 145 days (no opportunity to oviposit)	Female	Unmated : —
	Mated : 51 days (laid 21 eggs and 2 collapsed eggs)		Mated : 71 days (laid 23 eggs and 2 collapsed eggs)

In addition, a mated male lived for 26 days at room temperature, when it was transferred to a temperature of 25°C., and survived for a further 40 days ; and a mated female lived for 25 days at room temperature and 41 days at 25°C., having laid 3 eggs on the few hosts supplied to it. As in the case of *Ephialtes extensor* the term "collapsed egg" is applied to the empty chorion sometimes deposited by the female. The greatest number of eggs laid in one day was three, in addition to two collapsed eggs. As shown above, the greatest total oviposition observed in any one female was 23 eggs and 2 collapsed eggs. This figure would undoubtedly have been increased had a greater supply of hosts been available ; but after an initial attempt to breed *hemipterus* on larvae of *Cydia pomonella*, it was found that the correct host was *Ephialtes extensor*, and as this species itself was being studied, comparatively few larvae could be spared for the investigation of the biology of *H. hemipterus*.

The first larvae received from France were without any host cocoon, and until evidence was later obtained as to the host relationships of the species, it was found impossible to breed *hemipterus* to the adult stage. A female, which had been kept at room temperature, was supplied 10 days after its emergence with cocoons of *Cydia pomonella*. The larvae of *Cydia* had been given small sections of corrugated cardboard in which holes had been punched, and had made their cocoons in these. The female parasite showed great interest in these cocoons and inserted her ovipositor through the holes, but did not sting the larva or oviposit ; the female also showed interest in a naked larva taken from its cocoon, but did not attempt to sting it. Six days later the female was supplied with similar cocoons and with one not covered with strawboard. Only the larva in the latter cocoon was stung, the parasite feeding at the puncture ; the larva had been stung several times and one egg laid externally on it. On the following day, four larvae in cocoons were supplied and stung ; on opening the first three cocoons, the *Cydia* larvae were found to be paralysed and capable of only the slightest movements, but no eggs had been laid. The fourth cocoon was left with the female for 15 minutes after stinging. During this period the female waited with her antennae touching the surface of the cocoon ; she then inserted her ovipositor again. The larva, on the cocoon being opened, was found to be motionless, and in the cocoon was an egg. On the following day a cocoon was again supplied, and oviposition took place ten and a-half minutes after the stinging of the larva. In this case, the *Cydia* cocoon when presented to the parasite was slightly broken, and while the parasite was attempting to sting the larva, it several times tried to emerge through the break ; the parasite, however, beat its head violently with her antennae, and the larva retreated within the cocoon. The egg hatches in about four days at room temperature. The larva commences to feed on the body of the host ; where feeding has taken place, a dark brown spot, surrounded by a somewhat lighter brown ring, appears. No larva was reared beyond the third stage with *Cydia pomonella* as host. In one case, a host larva bore 19 feeding-marks by the time the parasite larva had attained the third stage, four days after eclosion from the egg. This frequent changing of position suggests that the parasite either found the host unsuitable or had difficulty in feeding.

When, subsequently, larvae of *H. hemipterus* were received with remains of *Ephialtes extensor*, larvae of the latter species were supplied to *hemipterus* females. The hyperparasites oviposited and bred readily on the *Ephialtes*, the process of oviposition being similar to that noted above. In one case, however, where the female was being watched under the microscope, it was observed that she inserted her ovipositor into one end of an unusually large cocoon, while the *Ephialtes* larva was observed, by light transmitted through the cocoon, to be at the other end. Thus, the female did not find the host larva with her ovipositor; she left the cocoon and returned to it again twice within five minutes, finally inserting her ovipositor and laying an egg. Undoubtedly this egg would have been damaged by the unparalysed host had it been allowed to remain. The parasites were reared to the adult stage without difficulty or undue mortality, using *E. extensor* as host. In one case a cocoon containing an *Ephialtes* pupa was by error supplied to the female; this was stung, and the female oviposited; from this egg a somewhat small *Hemiteles* developed.

Salt (1931, p. 498) concludes that it is the cocoon of *Cephus pygmaeus*, Linn., that provides the stimulus causing *H. hemipterus* to oviposit, since *hemipterus* examines an empty cocoon of *C. pygmaeus* with care, and often pierces it with the ovipositor; while the naked *Cephus* larva arouses no interest. A female of *hemipterus* showed interest in a naked *Cydia* larva, but did not oviposit. I have no record of naked *Ephialtes* larva being presented to a *hemipterus* female. Salt's conclusion is interesting in connection with the case when the *hemipterus* female oviposited without paralysing the host larva; and possibly explains the fact that the female will oviposit on *Cydia* larvae, though its young are apparently unable to complete their development thereon. For, in nature, when the female finds an *Ephialtes* cocoon, it must always be enclosed in that of the host *Cydia*; presumably the female can differentiate between a *Cydia* cocoon containing a cocoon of *Ephialtes* and one containing a *Cydia* larva, but in the absence of the desired host, the *Cydia* cocoon alone can provide the stimulus to oviposition. Salt records that *H. hemipterus* females, bred from larvae of *Cephus pygmaeus*, readily attack larvae of *Cydia pomonella* and *Ephialtes extensor*, while refusing to oviposit on larvae of *C. pygmaeus*. Eggs laid in this manner on larvae of *C. pomonella*, and transferred to larvae of *Cephus pygmaeus*, killed by immersion in hot water, were able to complete their larval development. Salt does not say, however, whether eggs laid on *Cydia pomonella* could complete their development on that host or not. Salt interprets these facts as indicating a definite selection of an alternate host by ovipositing females, bred from *Cephus pygmaeus*, and also that these females will not parasitise the host species from which they themselves developed, even when it is the only one available, and although it is entirely suitable for the development of their progeny. *Hemiteles hemipterus* adults emerge from their *Cephus* hosts in May and early June, and do not again attack *Cephus pygmaeus* until its larvae are full-grown and have constructed their cocoons, at the end of August, according to Salt. In these circumstances, an alternate host for *hemipterus* is desirable, if not essential, in spite of the longevity of the species recorded above; but in the case of *hemipterus* females bred from *Ephialtes extensor* larvae, the same host is available almost continuously and no alternate host is necessary. Unfortunately, no experiment was made to determine whether or not *hemipterus* females bred from *Ephialtes* larvae could oviposit on *Cephus* larvae.

Copulation was observed by a male with the female from whose egg it had been reared; this occurred two days after the emergence of the male, and 24 days after the emergence of the female, immediately after the male was put in the cage of the female. On the approach of the male, the female turned and walked away. The male followed and mounted, curving the tip of his abdomen around the left side of the ovipositor. Mating lasted half a minute, the female standing still, with the

tips of her antennae touching the ground and quivering. The male then walked away, the female remaining in the same position for a minute or two and subsequently becoming very active.

There are five larval stages; one individual, however, was observed to pass through six larval stages, and two individuals through four only. Below are given average times occupied by various phases of development at 25°C. (the figures given in brackets are, first, the number of individuals observed, and, second and third, the minimum and maximum duration of each phase); observations were made once daily:—

	Male		Female	
Incubation period	1.7 days	(15, 1, 2)	1.5 days	(2, 1, 2)
1st larval stage	1 day	(2, 1, 1)	1 day	(1)
2nd larval stage	1 day	(4, 1, 1)		
3rd larval stage	1 day	(5, 1, 1)		
4th larval stage	1 day	(5, 1, 1)		
5th larval stage to commencement of cocoon	1 day	(4, 1, 1)		
Spinning	1.6 days	(5, 1, 3)	1 day	(1)
Completion of cocoon to pupation...	4.5 days	(6, 4, 6)	10 days	(2, 10, 10)
Pupation to emergence of adult from cocoon	5.3 days	(6, 3, 7)		
Time spent by adult in cocoon ...	2 days	(4, 1, 3)		
Total period from deposition of egg to emergence of adult	16.2 days	(11, 12, 19)	16 days	(2, 16, 16)

The egg and larva of *Hemiteles hemipterus* were fully described and figured by Salt (1931); the specimens examined by the present writer are in close agreement with Salt's description. It is convenient to consider here the morphology of the larvae of *H. macrurus*, Ths., the biology of which is discussed below. Only cast larval skins of *macrurus* were available for examination; from these it was found that the facial rods, facial setae, and mouth-parts of *Hemiteles hemipterus* and *H. macrurus* are indistinguishable one from the other. In both species there is a range of variation in the setal arrangement, especially in the arrangement and number of the setae on the clypeus. With the small number of specimens of *macrurus* available, it was not possible to determine whether or no any particular arrangement of setae is more characteristic of *macrurus* than of *hemipterus*. Those specimens of *macrurus* examined certainly come within the range of variation of *hemipterus*.

(v). *Hemiteles macrurus*, Ths. (Ichneumonidae: subfam. Cryptinae).

No host records of this species were found in the literature. Morley (vol. ii, 1907) and Schmiedeknecht (vol. ii, 1904–06) record the species from Sweden and Hungary, and Morley mentions a single female captured in England. Five larvae of *H. macrurus* were received during the course of the present work in the French collections, but only one of these was accompanied by the cocoon and larval remnants of its host, which was *Ephialtes extensor*, Taschb. One male specimen of *H. macrurus* was bred in the laboratory on *E. extensor*.

Length of life of adults, at room temperature:—

♂ unmated	8 days
♀ unmated, no oviposition	9, 12, and 75 days
♀ unmated, laid four eggs	6 days

As these figures show, in most cases the adult life was very short. Adults, during life, were mistaken for those of *H. hemipterus*, of which numerous individuals were available, and consequently only two females of *macrurus* were given an opportunity

to oviposit. One of these was presented, three days after emergence, with cocoons of *Ephialtes* and of *Cydia pomonella*; she paid no attention to either. The following day she was seen to oviposit in the *Ephialtes* cocoon; on its being opened it was found to contain two eggs. The next day two more eggs were laid; the female died without further oviposition. The second female with which it was attempted to obtain eggs lived 75 days. Twenty days after emergence she was supplied with an *Ephialtes* cocoon, and for over an hour she tried to sting, but could not penetrate the cocoon. The cocoon was opened and the larva found to be alive; the female examined the open cocoon, beating the larva with her antennae; but did not oviposit or sting, although she put her ovipositor in the cocoon near the larva. The female took little notice of a *Cydia* cocoon, which was afterwards supplied to her. *Ephialtes* cocoons were subsequently kept in the cage of this female for fourteen days continuously, and at intervals after this period, but although she attempted oviposition, the cocoons were apparently impenetrable to her. The behaviour of this second female makes it appear probable that *Ephialtes extensor* is not the usual host of this parasite. In the case of the one male bred, the larval history was similar to that of *Hemiteles hemipterus*. Kept at a temperature of 25°C., the egg hatched in two days, and the adult emerged 17 days after the deposition of the egg, the adult insect having spent one day in the cocoon.

The eggs of *H. macrurus* are elongate and slightly curved; they are broader at the cephalic than at the caudal end. They measure 1.10 to 1.20 mm. in length, and 0.2 to 0.28 in greatest diameter. As in the case of *H. hemipterus*, the eggs are smooth and shining without surface sculpturing. The cocoon of *macrurus* is white in colour, and irregular in shape, conforming to the space remaining inside the *Ephialtes* cocoon, which is itself variable in shape. The larval head of this species has been discussed above, with that of *H. hemipterus*.

(vi). ***Cryptus sexannulatus***, Grav. (Ichneumonidae: subfam. Cryptinae).

No host records of this species have been found. Schmiedeknecht (1905, p. 449) gives as its geographical distribution, Middle and South Europe, and says it is rare.

Two cocoons of this species were received from Toul (M. et M.). One was without any host remnants; the other had been made inside a pupa of *Cydia pomonella*. From these cocoons two females emerged, which were supplied with cocoons of *Cydia pomonella*, for oviposition, 26 days after emergence. The female from the cocoon with no host remnants did not oviposit until 16 days later, although continuously supplied with *Cydia* cocoons; she laid 9 eggs and, in addition, stung and paralysed larvae without oviposition on several occasions. Unsuccessful attempts were made to rear adults from three of these eggs; the larvae, however, fed externally on the paralysed hosts for a time. The second female, that from the cocoon within the *Cydia* pupa, commenced to oviposit within a day of the first presentation of *Cydia* larvae. She laid 14 eggs in all; the greatest number laid in one day was 3, this occurring after the female had been kept without host larvae for oviposition for 17 days. These figures give no indication of the possible total oviposition of the species, since the females were not continuously supplied with hosts. Only males were bred, in spite of both females being caged with the male progeny of the one female. The two females lived 76 and 92 days respectively; males lived for 20, 24, and 42 days.

The process of oviposition occupies 10 to 12 minutes. After examination of the cocoon in its strawboard container with the antennae tips, the female inserts her ovipositor, using the sheath to grip its lower part. The sheath is then curved backwards and upwards, away from the ovipositor. The cocoon is explored with a few thrusts. If the larva is not found, the ovipositor may be withdrawn and entrance repeated elsewhere in the cocoon. On finding the larva, several sharp thrusts of the ovipositor are made; the female then remains still for three or four minutes. After this, vibration of the antennae and wings occurs, and movements

of the abdomen and ovipositor. The ovipositor is withdrawn and replaced in its sheath, the female leaves the cocoon. Feeding by the female on the larva was not observed. On opening the cocoon, a paralysed larva and usually one external egg were found.

The eggs were allowed to develop at a temperature of 25°C. Of six observed five hatched in two days, and one in three days. The larvae feed externally on the host and the duration of the larval stadia was noted. Each of the first three stadia occupies approximately one day, or slightly less. Typically the larvae have four larval stages, in the last of which little feeding is done, most of this stage being spent in the making of the cocoon. The cocoon is somewhat irregular in shape, and when first constructed is cream-white in colour; in a day or two it becomes darker. There is some variation in the final colour of the cocoon; of the two cocoons received from France, that contained in a *Cydia* pupa was dark amber-brown, while the other was very dark grey or black. One larva was observed to pass through six larval stages. The cocoon was completed in two cases in two days, and in one case in one day, from the commencement of the fourth larval stage. No observations could be made on the duration of the larval and prepupal stages, and the length of time spent by the adult in the cocoon, owing to the opacity of the latter; but three males emerged in 12, 9, and 11 days respectively, after the completion of the cocoon.

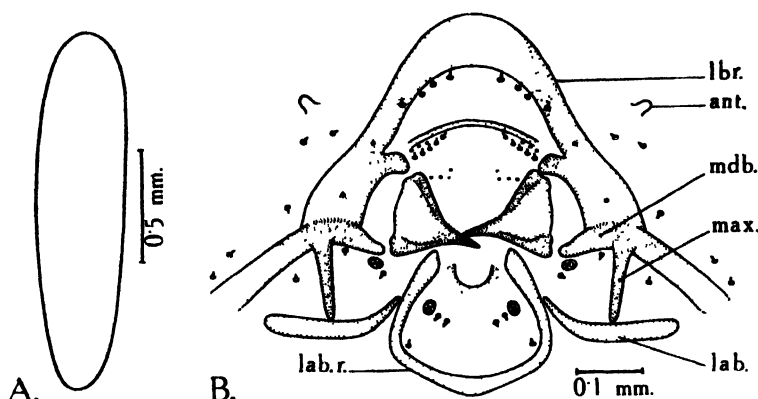


Fig. 6. *Cryptus sexannulatus*, Grav.: A. egg; B. facial rods and mouth-parts of mature larva; *mdb*, mandibular strut; *max*, maxillary strut; *lab*, labial strut; *ant*, antenna; *lbr*, labral strut; *lab.r*, labial ring.

The fact that one of the cocoons received from France was in a *Cydia* pupa is inexplicable; on examination, two larval skins, somewhat damaged but very similar to those of *C. sexannulatus*, were found between the skin of the host and the cocoon; and one last stage skin in the cocoon. The cocoon was large, and the *Cydia* pupal remains were somewhat broken and drawn apart, and closely attached to the cocoon. No evidence was found to suggest that in this case *C. sexannulatus* was hyperparasitic on another parasite of the pupa. As recorded above, in one case a female of *Hemiteles hemipterus* was supplied by mistake with a pupa instead of a larva of its host, *Ephialtes extensor*, and the *Hemiteles* larva fed externally on the pupa, and was reared to maturity. But a *Cydia* pupa has a much tougher skin than an *Ephialtes* pupa; and also the *Cryptus* larva must have fed internally on the *Cydia* pupa, since its larval skins were found inside the latter. Such internal feeding by an ectophagous larva would, in the absence of this evidence, have seemed completely impossible.

The egg of *C. sexannulatus* is ovoid, approximately 1.5 mm. in length and 0.35 mm. in greatest diameter. The surface is slightly sculptured, the markings running

longitudinally and being more distinct towards the smaller end of the egg. The yellow-coloured contents of the egg are visible through the transparent chorion. The newly hatched larva has a slightly sclerotized, rounded head and 13 body segments. It is of the usual shape for an ectophagous parasite larva, the body being almost parallel-sided for three-quarters of its length, whence it narrows to the posterior end. The body is densely covered with stout spines or hooks, which are directed posteriorly. The head has well-defined labral and labial areas, and the prominent, highly sclerotized mandibles are unserrated. The antennae are elongated papillae, in length four times their width at base. Serrations of the mandibles appear in the third stage. In the fourth-stage larva, the facial rods show a high degree of sclerotization. The labral or frontal struts join in front of the mouth, although they are less well-defined anteriorly than posteriorly. Anteriorly, they appear to have a reticulate structure. In each there are two small circular, transparent areas, opposite the mandibles. The frontal struts are fused to the mandibular struts, which bear condyles for the articulation of the mandibles. Each frontal strut gives off a short, broad branch directed inwards, at the posterior corner of which is another mandibular condyle. The mandibular struts bear posteriorly directed maxillary struts. The labial ring is broad and well defined. The labial struts are transverse for most of their length; but the inner ends are produced anteriorly along the sides of the labial ring. The upper margin of the clypeus is marked by a transverse sclerotized arch.

(vii). ***Microcryptus abdominator***, Grav. (Ichneumonidae: subfam. Cryptinae).

From the cocoon of a Lepidopteron, believed to be *Cydia pomonella*, collected at Annecy, Haute Savoie, there emerged a male *Microcryptus abdominator*, Grav. This was the only specimen of this species reared. The larval skin of the host was not identifiable, owing to damage and fungus attack. Schmiedeknecht (1904-06, p. 629) and Morley (1907, p. 37) state that *M. abdominator* is a very common species, occurring over the whole of Europe; but host records are few. Goidanich (1931) records it as a parasite of *Pyrausta nubilalis*, Hübn.; and Morley (*loc. cit.*) reared it from a puparium of a small Tachinid fly (probably *Digonichaeta setipennis*, Mg.). Goidanich further records *Eupteromalus nidulans*, Thoms., as a hyperparasite of *M. abdominator*.

The single male specimen of *M. abdominator* reared lived for 20 days at room temperature.

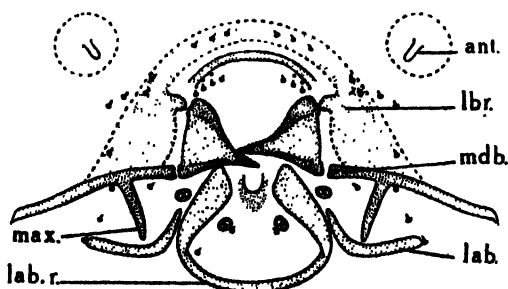


Fig. 7. *Microcryptus abdominator*, Grav., facial rods and mouth-parts of mature larva: *ant.*, antenna; *lbr.*, labral strut; *mdb.*, mandibular strut; *max.*, maxillary strut; *lab.*, labial strut; *lab.r.*, labial ring.

In the last-stage larva of *M. abdominator*, the labral struts join each other anteriorly, and posteriorly are fused with the mandibular struts, but are only heavily sclerotized around the condyles which they bear for the articulation of the mandibles. The mandibular strut has as a branch the maxillary strut. The anterior arms of the labial ring are flat and ribbon-like. Labial struts are present, supporting the labial ring. The mandibles carry on their antero-ventral edges a few coarse teeth,

which become shorter and less pointed towards the point of the mandible. The antennae are almost parallel-sided, and twice as long as their diameter, mounted on small papillae within clear, circular areas of cuticle.

(viii). ***Spillocryptus incubitor***, Ström. (Ichneumonidae: subfam. Cryptinae).

This species has been recorded from the following hosts:—

Hymenoptera :

Cimbex sp. (TENTHREDINIDAE) (De Gaulle, 1908).

Hylotoma rosae, L. (TENTHREDINIDAE) (De Gaulle, (1908).

Lygaeonematus (*Nematus*) *erichsoni*, Hartig (TENTHREDINIDAE (Britton, 1916).

Trichiosoma sp. (TENTHREDINIDAE) (De Gaulle, 1908).

One female of this species was reared from its cocoon, within a *Cydia* pupa, collected at Castagners, near Antibes. Fifty-four days after the emergence of the female, a cocoon containing a Codling Moth larva was put in the cage. The female excitedly examined the cocoon with the tips of her antennae and inserted her ovipositor, the ovipositor-sheath being used during the insertion, and afterwards returned to a horizontal position. The female remained with her ovipositor in the cocoon

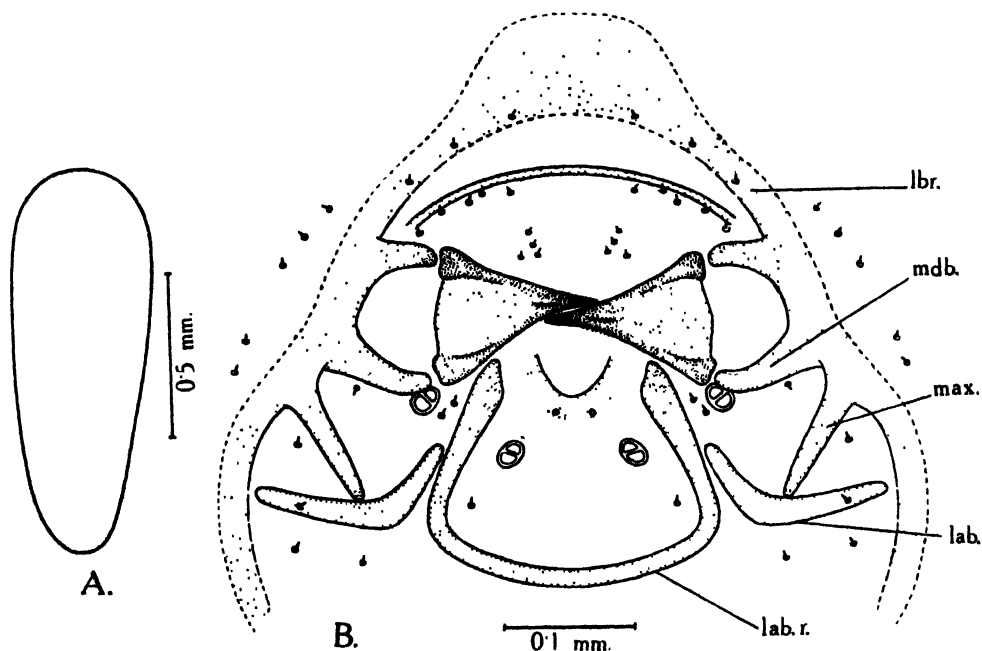


Fig. 8. *Spillocryptus incubitor*, Ström.: A, egg; B, facial rods and mouth-parts of mature larva; *lbr.*, labral strut; *mdb.*, mandibular strut; *max.*, maxillary strut; *lab.*, labial strut; *lab.r.*, labial ring.

for over three minutes; on subsequent examination, the larva in the cocoon was found to be paralysed, its heart beating feebly, and beside it, in the cocoon, was an egg. The following day, a second cocoon was supplied, and was stung in a similar manner, but the female withdrew her ovipositor after stinging the larva, and re-inserted it later to oviposit. Two hours later, another larva was stung, but the egg laid consisted of an empty chorion only. Several larvae were stung during the next fortnight, but no more eggs were laid. The female lived, in all, for 72 days. Of the two eggs obtained, only one hatched; the larva fed externally on its host and moulted once before dying.

The cocoon collected was (as in the case of *Cryptus sexannulatus* recorded above) large, and enclosing it was an almost complete *Cydia* pupa. The pupa was either fully extended when the cocoon was made, and the parts contracted when subsequently it broke, or else it was already broken at the time of the spinning of the cocoon. Inside the cocoon were found the larval and pupal skins of the parasite; and on a part of the outside of the cocoon that was not covered by the *Cydia* pupa was found a Hymenopterous larval skin which was damaged but could not be distinguished from a second-stage *S. incubitor* skin obtained by breeding in the laboratory. As in the case of *Cryptus sexannulatus*, this is apparently a case where a parasite fed internally on a *Cydia* pupa (although here the second-stage skin was not found actually between the cocoon and the pupa skin), while in the laboratory eggs were laid, and a larva fed externally on a paralysed host larva. The facts are apparently irreconcilable.

The facial rods of *S. incubitor* are slightly sclerotized. The frontal and mandibular struts are fused, the outer margin of the combined strut being indistinct. An anterior and a posterior point of articulation for the mandibles are present and are highly sclerotized, as is the maxillary strut. Anteriorly, the frontal struts of each side are poorly developed, but appear to fuse in front of the mouth. The anterior margin of the clypeus is more distinctly marked by a sclerotized arch. The mandibles are tetrahedral in shape and bear on the lower surface two rows of teeth; one row is situated on an edge, the other on a ridge on the lower surface of the mandible. The arms of the wide labial ring are broad and flattened anteriorly. The labial struts closely support the labial ring. The egg of *S. incubitor* is approximately 1.14 mm. in length, by 0.43 mm. in greatest diameter; it is almost twice as broad at the cephalic as at the caudal end and both poles are rounded. The egg is white and shining, and its surface is faintly etched.

(ix). ***Ascogaster quadridentatus*, Wesm. (Braconidae: subfam. Cryptogastrinae).**

This species has been recorded from the following hosts:—

Lepidoptera:

- Argyroplote variegana*, Hb. (TORTRICIDAE) (Sarra, 1918).
- Argyrotaxa (Dictyopteryx) heparana*, Schiff. (TORTRICIDAE) (André-Marshall, vol. iv, 1888).
- Cacoecia (Tortrix) rosana*, Linn. (TORTRICIDAE) (André-Marshall, t.c.).
- Cydia molesta*, Busck (TORTRICIDAE) (Allen, 1932).
- C. pomonella*, Linn. (TORTRICIDAE) (Sciara, 1915).
- Eucosma ocellana*, F. (TORTRICIDAE) (Woroniecka, 1926).
- E. (Pardia) tripunctana*, F. (TORTRICIDAE) (André-Marshall, t.c.).
- E. solandriana*, Linn. (TORTRICIDAE) (André-Marshall, t.c.).
- Eupithecia absinthiata*, Clerck (GEOMETRIDAE) (André-Marshall, t.c.).
- Hyponomeuta padellus*, Linn. (TINEIDAE) (André-Marshall, t.c.).
- Laspeyresia (Opadia) funebrana*, Tr. (TORTRICIDAE) (André-Marshall, t.c.).
- L. (Endopisa) nigricana*, Steph. (TORTRICIDAE) (André-Marshall, t.c.).
- L. (Carpocapsa) splendana*, Hb. (TORTRICIDAE) (André-Marshall t.c.).
- Pandemis (Tortrix) heparana*, Schiff. (TORTRICIDAE) (André-Marshall, t.c.).
- Recurvaria nanella*, Hübn. (TINEIDAE) (Puppini, 1930).
- Spilonota (Hedya) ocellana*, Fab. (TORTRICIDAE) (André-Marshall t.c.).
- Laverna hellerella*, Dup. (= *Crysoclista atra*, Haw. ?) (TINEIDAE), (André-Marshall, t.c.).
- Hyponomeuta malinellus*, Zell. (TINEIDAE) (André-Marshall, t.c.).

Further, Schwangart (1918) records *A. quadridentatus* from two Tortricids, *Clysia ambiguella*, Hb., and *Polychrosis botrana*, Schiff., but does not say definitely whether the parasite was bred from both hosts, or only from one or other of them. The references found gave a range of France, Poland, Italy, Germany, Austria, Cyprus; André-Marshall (1888) gives as its habitat the whole of Europe.

At the commencement of the work on the parasites of the Codling Moth at Farnham House Laboratory, a shipment of approximately 200 larvae, stated to be parasitised by *Ascogaster carpocapsae*, Vier., was received from Dr. Newcomer, of Yakima, Washington. The British Museum (Natural History) having no representatives of the species *A. carpocapsae*, Vier., specimens were submitted when adults of the species emerged. These were examined by Dr. C. Ferrière, who could find no difference between them and *Ascogaster quadridentatus*, Wesm.; in consequence, the name *A. quadridentatus* was used in the laboratory both for the specimens from the French collections and for those from Yakima. *A. carpocapsae*, Vier., has been widely reported from various parts of America as a parasite of the Codling Moth, but only one reference to its occurrence in Europe has been found (Bragina, 1926). In a recent paper (1932), Cox gives the following list of hosts of *Ascogaster carpocapsae*, Vier.

Lepidoptera :

Ancylis comptana, Froehl. (TORTRICIDAE).

Cydia molesta, Busck (TORTRICIDAE).

C. pomonella, L. (TORTRICIDAE).

Gelechia confusella, Cham. (TINEIDAE).

Polychrosis viteana, Clem. (TORTRICIDAE),

and records *Dibrachys cavus*, Wlk., as a hyperparasite.

Adults of *Ascogaster 4-dentatus*, Wesm., emerged from the collections stored in the unheated outdoor insectary on the following dates :—

1929 :	June 11, 28	July 8, 12
Number emerged :	1 1	2 1

In 1929, the first *Cydia pomonella* emerged on the 29th May, and the last on the 1st August, with the peak of emergence on the 19th June.

1930 :	June 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25
Number emerged :	1 4 3 2 3 4 1 4

	June 26, 27, 28, 29, 30	July 1, 2, 3, 4, 5, 6, 7, 8, 9, 10,
Number emerged :	10 1 7 4 14	1 3 3 2

	July 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25
Number emerged :	3 1 1

The emergence of *Cydia pomonella* in 1930 commenced on 5th June, reached a maximum on 21st June, and the last moth emerged on 11th August. Unfortunately the sex of the emerging *Ascogaster* was not determined, so it is not known if one sex emerged before the other.

Oviposition.

The female searches the leaf, or other material, on which the egg of *Cydia pomonella* has been laid, tapping continuously with the tips of her antennae until the egg is located; the egg is examined briefly, and the female steps over it, so that the end of her abdomen comes to be above the egg. The abdomen is slightly bent down, and the female searches for the egg with her ovipositor; if, as frequently happens, she has gone too far forward, or is not in a convenient position, the female turns round, finds the egg again with her antennae, and proceeds as before. The ovipositor is inserted with one or two thrusts of the abdomen and the egg is laid; at the moment of stinging, the hind legs are usually raised and lowered in time with the thrust of the abdomen, the female standing on the pro- and meso-thoracic

legs. After the ovipositor has been withdrawn the surface of the egg around the puncture is repeatedly dabbed with the tip of the ovipositor sheath. The parasite egg is deposited in the cytoplasm of the host egg and not in the developing embryo. Cox (1932) states that with *A. carpocapsae*, Vier., eggs laid in host eggs in the advanced black-dot stage fail to develop, but with *A. quadridentatus*, Wesm., eggs have been laid in *Cydia* eggs in the early black-dot stage and have hatched and entered the host successfully. After oviposition, the female may examine the egg with her antennae, or she may proceed to search for another egg immediately; in no case was a female seen to feed on any juices at the puncture. An isolated female in a

Day of life	A ♀ mated ; ♂ died on 9th day			B Unmated ♀		
	Hosts stung	Eggs laid	Time taken in minutes	Hosts stung	Eggs laid	Time taken in minutes
1	No hosts supplied			No hosts supplied		
2	62	42	90	49	27	90
3	95	47	125	60	41	75
4	52	39	70	59	39	60
5	50	23	50	No hosts supplied		
6	70	39	90	49	36	60
7	50	32	70	49	34	55
8	50	19	75	49	39	50
9	50	28	105	49	41	30
10	24	14	110	49	40	33
11	9	5	35	49	36	45
12	No hosts supplied			No hosts supplied		
13	18	6	65	49	38	55
14	18	1	55	49	37	50
15	10	3	30	49	34	50
16	20	10	40	49	27	50
17	19	2	45	49	31	55
18	19	7	50	49	32	60
19	17	8	50	No hosts supplied		
20	6	0	20	49	35	70
21	13	0	19	49	22	60
22	4	0	12	49	14	75
23	7	0	7	28	15	47
24	4	0	4	28	22	40
25	8	0	11	28	20	35
26	6	0	6	No hosts supplied		
27	6	0	5	28	19	57
28	2	0	3	28	15	50
29	♀ dead			28	18	28
30				28	9	110
31				21	2	75
32				21	10	105
33				No hosts supplied		
34				} ♀ now feeble and could not locate egg with ovipositor ♀ dead		
35						
36						

glass tube usually will not oviposit a second time in an egg until some 20 minutes have elapsed from the time of the first oviposition, although she will lay freely in other eggs in the meanwhile. The fact that a female later will lay a second time in an egg suggests that fluids escaping from the puncture emit an odour which is dissipated as the fluids evaporate, and that when this has happened a second oviposition may take place. Occasionally, a female will lay a second egg in the same host within two or three minutes.

In two cases only was the total number of eggs laid by a female determined. The females used for this purpose were removed from their cages daily; Codling

Moth eggs were placed three-eighths of an inch apart on a cork sheet under a petri dish, and a female introduced. Host eggs were removed as they were stung, and dissected to find how many parasite eggs had been laid. The table above shows the result of this experiment.

Individual B was dissected after death, and the ovaries were found to contain 10 eggs ; in all the female laid 733 eggs. Individual A laid 325 eggs ; no examination of the ovaries was made. Two eggs were laid in one host, when other hosts were available, on 16 occasions by A, and on 1 occasion by B. The females would have stung more eggs each day if they had been supplied, except towards the end of their lives ; but after the first week few eggs were laid in the last hosts supplied each day, and it is doubtful whether any increased oviposition could have been secured. With increasing age, a greater time was taken over oviposition ; the females became unsteady on their feet, and experienced difficulty in locating the eggs with their ovipositors ; also an increased amount of time was spent in cleaning antennae and resting between successive ovipositions. In both cases, an increase in the number of eggs laid occurred on the third day, followed by a more or less steady decline. *Ascogaster* females will oviposit very shortly after emergence from the cocoon, but in these two cases no eggs were supplied until one day later.

Ascogaster was bred on a large scale for shipment. For such mass rearings a number of *Cydia* eggs were put in a petri dish with female parasites for a varying time ; the time and respective numbers of hosts and parasites being adjusted according to the age and vigour of the females. On one occasion four females were confined for 45 minutes with 21 eggs. These eggs were afterwards dissected with the following results : 4 eggs were unparasitised ; 7 eggs contained 1 parasite egg ; 6 eggs contained 2 parasite eggs ; 4 eggs contained 3 parasite eggs. In no case did more than 1 parasite develop in a Codling Moth larva.

Hatching of egg and larval history.

At a temperature of approximately 70°F., the parasite egg hatches in 2 to 3 days, and the larva enters the host embryo. Its growth is slow and the parasite is still in the first larval stage when the host has completed its larval development, left the apple and made its cocoon. The presence of the parasite stunts the host, which when fully fed is only about one-quarter the size of an unparasitised caterpillar. If the host hibernates, the parasite passes the winter in the first larval stage. Otherwise rapid development of the parasite now takes place. It moults twice, and emerges from the host larva. The glistening white cocoon is spun, the larva pupates, and finally the adult emerges.

The Adult.

Copulation may take place immediately after emergence, before the insects have fed at all. In the presence of a female, the male becomes violently excited and approaches her with wings raised and antennae vibrating. The female usually retreats and is pursued by the male, until, reaching her, he mounts ; his abdomen is curved downwards and under that of the female, and mating takes place. The act is very brief, lasting only a few seconds, and the female commences to move on, shaking off the male. The female, whether fertilised or not, can lay very soon after emergence, before taking any food. Adults were fed on raisins and sugar, and supplied with a jar containing cotton-wool, soaked in water and covered with tiffany. The insects are strong fliers ; and the fusion of the abdominal tergites to form a dorsal and lateral shield for the abdomen makes them resistant to damage in handling. This hardiness, coupled with the readiness with which they mate and oviposit, makes the species ideal for mass rearing in the laboratory.

Most of the parasites were kept in large numbers in each stage ; a few, however, were isolated, and the details of their length of life are as follows :—

Mated ♂♂ : 8, 5, 1, and 9 days.

Mated ♀ not allowed to oviposit : 36 days.

Mated ♀♀ allowed to oviposit : 36 and 31 days.

Unmated ♀ allowed to oviposit : 35 days.

All were kept at a temperature of 70°F. and fed.

In addition, the length of life is given below of individuals kept in large numbers in each cage. In these cages the insects emerged on one of three successive days ; the length of life given is calculated from the middle of these days, and thus may be one day greater or less than the actual life.

	Males				Females			
	No. in cage	Max. life (days)	Min. life (days)	Average (days)	No. in cage	Max. life (days)	Min. life (days)	Average (days)
Cage 1	21	24	8	15.3	15	33	1	21.0
„ 2	6	29	16	19.5	16	44	6	27.8
„ 3	10	25	3	16.1	27	47	4	24.9
„ 4	1			5.0	8	42	14	29.1

As in the case of the isolated individuals, these parasites were kept at 70°F. and were fed. Females in Cage 1 were allowed to oviposit on the 15th day of their lives only ; those in Cage 2 oviposited daily from the 13th day to the 25th, and those in Cage 3 daily from the 13th to the 23rd day. Females in Cage 4 did not oviposit.

Mass Breeding.

For the breeding in numbers of *Ascogaster*, a technique for raising stocks of the Codling Moth was first developed. The moths were confined in cages consisting of cardboard cylinders, 9 inches in diameter and 9 inches long, with the axis of the cylinder horizontal ; the cylinders were lined with paper, held in place by wire paper-clips, and the ends were covered with cellophane. Every morning the moths were removed and the paper and cellophane changed. Eggs were laid by the moths on both paper and cellophane ; eggs laid singly and in pairs were removed with a small piece of the material on which they had been laid, and were pinned, through the cellophane or paper, to sheets of cork ; larger egg-masses were divided or discarded. For the production of parasites, *Cydia* eggs were exposed to *Ascogaster* females under petri dishes, and afterwards pinned to apples. The host larvae hatched, entered the apples, and when fully fed, emerged and made their cocoons. These larvae were either allowed to continue their development, or were cooled and subsequently put in the refrigerator for hibernation or shipment.

Owing to the impossibility of determining, without dissection, whether or not any individual was parasitised until after the caterpillar had left the apple (when the small size of parasitised larvae was at once apparent), no figures are available for mortality in the egg-stage, and in the larval stages prior to the making of the host's cocoon. A series of unparasitised and parasitised *Cydia* larvae, bred under identical conditions, hibernated in a refrigerator at 31°F. for from 3 to 5 months, and were then slowly warmed and finally kept at a temperature of 75°F. and 80 per cent. R.H. From these :—

211 *Ascogaster* adults emerged.
170 parasitised larvae died (42.5%).
10 *Ascogaster* larvae died in cocoon.
2 *Ascogaster* pupae died in cocoon.
7 *Ascogaster* adults died in cocoon,
or emerging therefrom.

1,337 *Cydia* adults emerged.
127 *Cydia* larvae died (8.37%).
53 *Cydia* pupae died.

The number of *Ascogaster* adults emerged includes two which died shortly after leaving the cocoon. Various conditions of temperature and humidity were tried, but in all cases there was a large mortality in the parasitised larvae. The apples containing larvae were kept in covered trays containing strips of corrugated cardboard; a few of the larvae, on emerging from the apple, made their cocoon in the cardboard, but most spun up in the angles of the tray. These larvae had to be removed to glass tubes, containing sections of corrugated cardboard, and there spun again; it seems probable that the second spinning was too much for the lowered vitality of the parasitised larvae, resulting in their premature death, and the death of the contained parasites. A similar high mortality was noticed in larvae which were judged from their size to contain *Ascogaster*, in the French collections, and which, when removed from their cocoons on the trees, were compelled to spin fresh cocoons. This mortality is a most serious defect in the method of breeding adopted; but it could not be overcome, since it was essential to be able to remove the cocoons from the apple trays, and, however many strips of corrugated cardboard were provided, a large number of larvae always spun up elsewhere in the trays. A favourite place was in the crevice between the side of the tray and the beading round the inside of the lid; any hole or indentation in the wood was enlarged by the larvae and utilised, tunnels being made right into the wood of the trays. Such tunnels were filled with plasticine before the tray was used for subsequent batches of apples. The trays in use were made of soft plywood; some advantage might have been gained, at a considerable expense, by using trays of oak or other hard wood, but even so, a large number of larvae would have made their cocoons in the corners and angles of the tray.

Egg and Larval Morphology.

The newly-laid egg (fig. 9 A) is from 0.17 to 0.18 mm. in length, and from 0.05 to 0.06 in greatest width, sub-reniform, and of considerably greater diameter towards the cephalic pole than towards the caudal pole. The contents are granular and give the egg a dull white appearance. The surface is smooth. At the time of oviposition the contents do not fill the egg, but it is completely filled three or four hours later. The developing larva is visible 24 hours after oviposition at 65°F.

During the first-stage the larva undergoes a remarkable change in size and appearance. The newly-hatched larva is 0.19 to 0.2 mm. in length, and about 0.06 mm. in greatest width. The head is large and widest at a point two-thirds of its length from the anterior end. The body consists of thirteen segments, is narrow and vermiform, and roughly twice as long as the head. The mandibles are about 0.025 mm. long, and sharply pointed. Anterior to the mouth there are two small raised sections of the cuticle, each bearing four or five tubercles. The posterior margin of the mouth is produced into a spatulate process. Antennae are not visible. No part of the head is densely sclerotized, but slight thickening of the cuticle is noticeable round the mouth. During the course of the first stadium the larva increases to ten times its original length, and five times its original width; that is to say, it increases to 250 times its original volume. The head does not increase in size at all during the process; from being considerably wider than the body, it comes to be a very slightly protruding spot on the first body segment. At the same time a portion of the rectum is gradually invaginated. Fig. 9 shows the various stages in the growth of the larva. In the young first-stage larva the head is described above; the larva in fig. 9 C is about

one-third grown, and shows greatly increased body width, while the head is broadened at its junction with the body and drawn into the first body segment. In the lateral view of the half-grown first-stage larva (fig. 9 D) the process has gone further, and it is seen that the walls of the head are coming to lie along the walls of the first body segment, which now contains the large cerebral ganglion. Figs. 9 E and F show the mature first-stage larva, in which the mandibles are found on a slight hillock on the first body segment, and from them run small cuticular folds, indicating the outline of the head. Meanwhile, the rectal evagination has proceeded. Fig. 10 A shows the quarter-grown larva, in which the rectum is slightly protruding. A portion of the

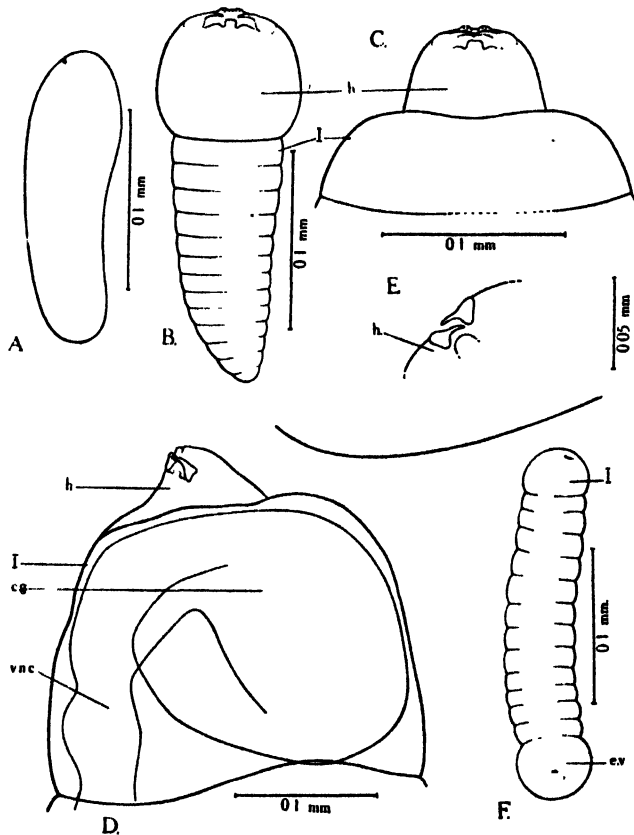


Fig. 9. *Ascogaster quadridentatus*, Wesm.: A, egg; B, young 1st stage larva, one-third grown; C, head and first thoracic segment of 1st stage larva, one-third grown; D, lateral view of head and first thoracic segment of 1st stage larva, half-grown; E, head and first thoracic segment of fully-grown 1st stage larva; F, fully-grown 1st stage larva; h, head; I, 1st body segment; cg, cerebral ganglion; vnc, ventral nerve cord; ev, evaginated rectum; B, C and E are drawn to the same scale, D, to a smaller scale.

rectal tissue, composed of elongated columnal cells, has bulged outwards; most of the cell growth has taken place ventral to the junction of the mid and hind g.i.s. In fig. 10 B, of a half-grown larva, the process has gone further, and a considerable amount of rectum is evaginated.

The mature first-stage larva (fig. 9, F) consists of a minute head, large spherical first body segment, and twelve other segments, succeeded by a caudal segment, consisting of the evaginated rectum; the caudal segment is similar in size and shape

to the first body segment, but under the microscope is seen to be composed of elongated cells, radially arranged. Cox (1932) describes the mature larva of *Ascogaster carpocapsae*, Vier., as consisting of head and thirteen segments, and states that "the hind intestine is located in the anal segment, and extends to the evaginated rectum, which is located on the dorsal surface of the caudal segment." He evidently regards what the present writer describes as the first body segment of the mature larva as the head; and the evaginated rectum as the thirteenth body segment together with the rectum. A study of a series of first stage larvae of varying development renders this view untenable.

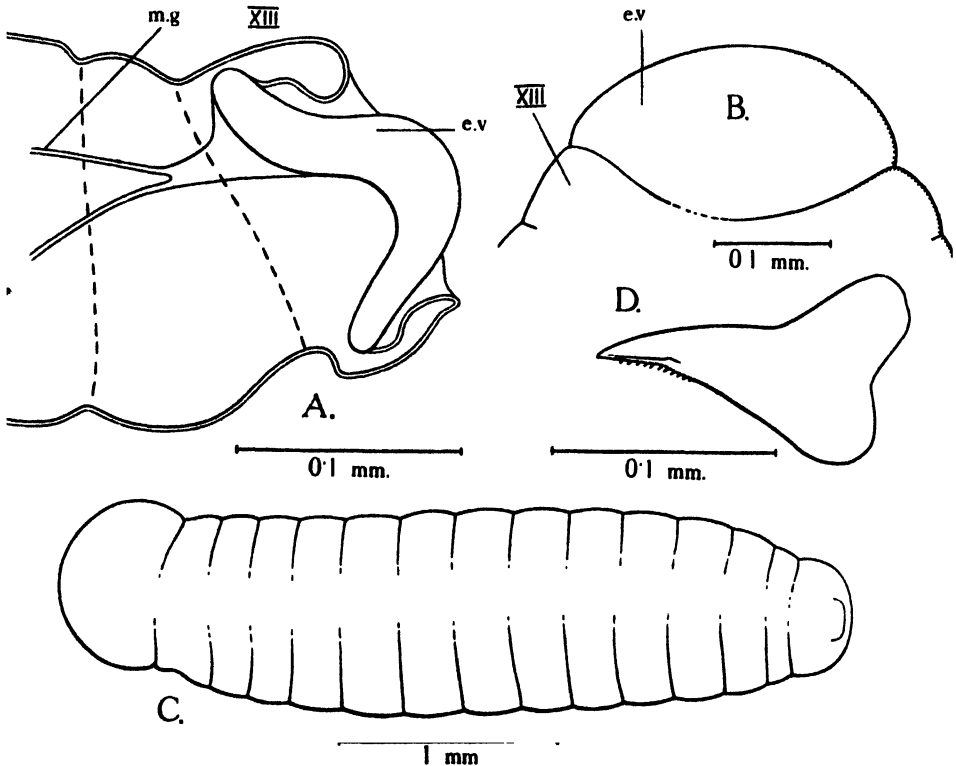


Fig. 10. *Ascogaster quadridentatus*, Wesm.: A, lateral view of quarter-grown 1st stage larva, showing rectal evagination; B, dorsal view of half-grown 1st stage larva; C, second-stage larva; D, mandible of second-stage larva; *mg*, midgut; *ev*, rectal evagination; *XIII*, thirteenth body segment.

According to Thorpe (1932), similar vesicles are present in second stage larvae of numerous Braconids; in *A. quadridentatus* its development is gradual during the first stage. The function of the vesicle is doubtful; Thorpe concludes that it is not the sole, or even the most important organ, of respiration. But its development during this stage is most interesting. The mature larva, as stated above, is about 250 times the volume of the newly-hatched larva; further, the head of the newly-hatched larva is at least one-third of the volume of the whole larva. Owing to the disappearance of the head in growth the cuticle of the body alone must expand sufficiently to accommodate the increase in bulk. As the anal vesicle occupies one-sixth of the volume of the mature larva, it seems probable that it is the emission of this vesicle that enables the larva to grow to this degree in one larval stage. A vesicle developed in this way might subsequently become useful to the larva as a respiratory organ or otherwise.

Cox (1932) describes four larval stages of *Ascogaster carpocapsae*. Of these, he says the second stage is without mandibles, and is of short duration, lasting about two or three days. According to him, the third stage larva differs from the second in the possession of mandibles, and in being less elongate, widest in the middle, and tapering towards the head and anal segment; whereas, in the second stage the body is parallel-sided. The present writer found no stage without mandibles, and nothing to suggest the presence of more than one stage between the first and the last; a smaller number of larvae of this stage were examined than of the first stage, and it is possible that larvae of the stage called, by Cox, the second, were missed. But apart from the most remarkable lack of mandibles in this stage, there is no difference between Cox's second and third stages that might not be caused by the growth in the second larval stage. Vance (1932) describes only three larval stages in the closely allied *Chelonus annulipes*, Wesm. The larva of the second observed stage was from 3.5 to 4.5 mm. in length, and from 0.5 to 1.1 mm. in greatest breadth. The head is small, and the labium appears as a prominent transverse ridge. The

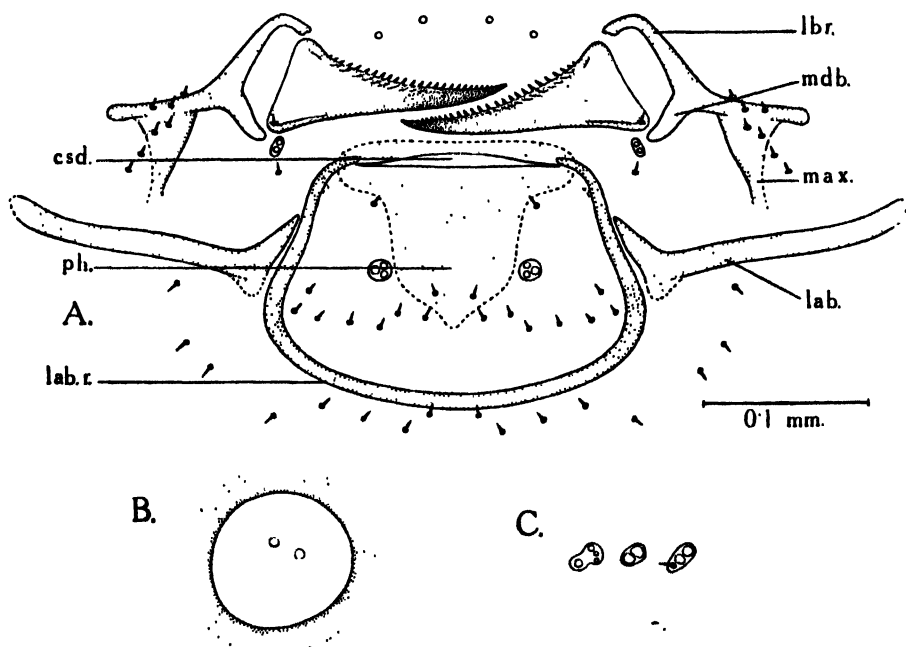


Fig. 11. *Ascogaster quadridentatus*, Wesm., full-grown larva: A, facial rods and mouthparts; B, antenna; C, labial sensoria of three individuals; *lbr*, labral strut; *mdb*, mandibular strut; *max*, maxillary strut; *lab*, labial strut; *lab.r*, labial ring; *csd*, opening of common silk duct; *ph*, position of pharynx below cuticle.

stout mandibles are very slightly sclerotized, and bear on their posterior ventral angle a single row of serrations. The larva consists of a head, thirteen body segments, and an evaginated rectum, and not a head, twelve segments and an evaginated rectum, as figured by Cox (1932).

In the last-stage larva the rectum is no longer evaginated, and there is a head followed by thirteen body segments. The larva is from 5.45 to 5.9 mm. in length, and about 1.45 mm. in greatest width. The most prominent feature of the head-capsule is the highly sclerotized labial ring; this is incomplete anteriorly, but overlies the sclerotized pharynx and thus appears, at first sight, to be complete. Within the labial ring is a narrow, transverse slit, the opening of the common silk duct. The mandibles are elongated structures, sclerotized to a moderate degree, with their

fine points anteriorly directed ; each bears a row of serrations on their anterior ventral angle. A Y-shaped rod, composed of frontal and mandibular struts, gives two points of articulation for the mandibles. The mandibular strut gives off as a branch the maxillary strut ; this is usually broad and well developed, but there is much variation in this character, and in some specimens it is almost absent. On the dorsal surface of the head are the antennal areas ; these are circular areas of clear cuticle, each containing two short conical papillae, the whole being surrounded by a sclerotized ring of cuticle. There are two small papillae on each side of the clypeus. The other sensorial structures and setae of the head are somewhat variable. Within the labial ring are the labial sensoria, each consisting of a sclerotized area bearing two three, or four small papillae, or two papillae and one seta. The maxillary sense-organ consists of two or three papillae on a sclerotized base. Below the labial sensoria there are eight or nine setae on each side, and about seven occur over the mandibular and maxillary struts.

(x). ***Meteorus chrysophthalmus***, Nees (Braconidae : subfam. Polymorphinae).

This species has been recorded from the following hosts :—

Lepidoptera :

Cochlidion (Heterogenea) limacodes, Hübn. (LIMACODIDAE) (André-Marshall, 1891–1901).

Eurhodope (Rhodophaea) suavella, Zinck. (PYRALIDAE) (André-Marshall, 1891–1901).

Eucosmia certata, Hübn. (GEOMETRIDAE) (André-Marshall, 1891–1901).

Crocallis elinguaris, L. (GEOMETRIDAE) (Wagner, 1929).

Gonodontis (Odontoptera) bidentata, Clerck (PYRALIDAE) (André-Marshall, 1891–1901).

Loxostege sticticalis, L. (PYRALIDAE) (Esterberg, 1931).

Cocoons of this species were collected at Elbeuf and Grignon, but they were sent to the laboratory without the remains of their hosts. One *M. chrysophthalmus*, Nees, emerged from the collections of larvae at Elbeuf ; the skin of the host of this specimen was unidentifiable, but was not *Cydia pomonella*. In all, nine cocoons of this species were received ; and as no moths other than the Codling Moth emerged from these collections, it would seem probable that the parasite's host was *Cydia pomonella*. The only alternative is that nine caterpillars of another species occurred, and were all parasitised by *Meteorus*. The specimen, a male, from the collection of larvae kept in the unheated insectary, emerged on 13th May 1930 ; the cocoons received were kept in the laboratory, and adults emerged during the winter. The Field Agent observed at Grignon, in November and December, that many cocoons of *Meteorus* were empty, the adults having emerged ; this observation, coupled with the emergence of an adult in May, from a host larva collected in October, suggests that *Meteorus chrysophthalmus* adults emerge in the autumn, and that the females then attack host caterpillars, in which the young parasite larvae pass the winter. The possibility of the adult female's living through the winter cannot be ruled out, as one lived in the laboratory for 130 days, at room temperature. Males lived 31, 35, and 40 days. An unsuccessful attempt was made to breed *Meteorus* on *Cydia* larvae of various stages ; but owing to pressure of other work, the attempts were discontinued after a short time.

The cocoon of *M. chrysophthalmus* is spindle-shaped, about 9 mm. long by 2.5 mm. broad. The outer layers of silk are rather coarse and white in colour. The inner layers are finer and buff-coloured ; silk of both layers is used to form a solid plug inside each end of the cocoon, the internal space being thus truncated. The facial rods of the mature larval head are shown in fig. 12. The posterior portion of the labial ring is indistinct. The labial strut has an anteriorly directed branch, which runs to the posterior angle of the base of the mandible. Another strut lies parallel

to the labial strut, with its inner end near the base of the mandible. Salt (1931, p. 532) figures the facial rods of *Microbracon terebella*, Wesm.; in this species the mandibular, maxillary and labial strut have fused to form a quadrilateral structure, at the anterior inner angle of which is the point of articulation of the mandible. Possibly the facial struts of *Meteorus chrysophthalmus* have developed through a stage similar to that of *Microbracon terebella*; the mandibular strut has degenerated (in one specimen examined it was small and ill-defined), the articulation of the mandible has been transferred to the maxillary strut, and the connection between the mandibular strut and the maxillary strut has disappeared. The anterior mandibular point of articulation consists of a small and ill-defined thickening of the cuticle. No frontal arch is present. The mandibles are short and blunt, with their points anteriorly directed. Within the labial ring are two sense-organs; each consists of a circular, sclerotized area, slightly conical, enclosing a clear area of cuticle, and bearing one or two papillae. The maxillary sense-organs are similar, but oval in shape, and the enclosed area is larger. There is on each side a row of four setae on the anterior margin of the clypeus; other setae are shown in the figure. The antennae are similar to those of *Ascogaster*, consisting of a circular area of clear cuticle, bearing two small papillae.

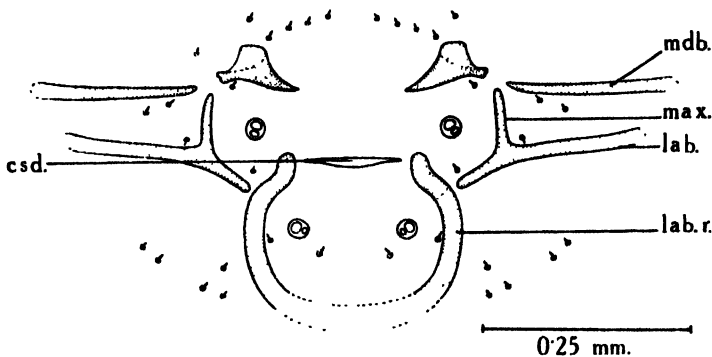


Fig. 12. *Meteorus chrysophthalmus*, Nees, facial rods and mouth-parts of full-grown larva: *mdb*, mandibular strut?; *max*, maxillary strut?; *lab*, labial strut; *lab.r*, labial ring; *csd*, opening of common silk duct.

(xi). ***Dacnusa* sp.** (Braconidae: subfam. Exodontinae).

The genus *Dacnusa*, and the sub-family to which it belongs, are parasites of Diptera, records having been found of the occurrence of members of the genus as parasites on various species of the following families: AGROMYZIDAE, CHLOROPIDAE, PSILIDAE, ANTHOMYIIDAE and DROSOPHILIDAE.

Two individuals, which were identified as being of this genus, emerged on 26th May 1930, in a cage containing Codling Moth larvae, stored in the unheated insectary. In this cage three *Arrhinomyia tragica*, Mg. (TACHINIDAE) emerged, parasites of the Codling Moth. When all emergence from the larvae had ceased, a search was made for parasite cocoons; three puparia of *Arrhinomyia* were found, from which adults had emerged, but no trace of cocoons of *Dacnusa*. No other Diptera emerged in this cage. If *Dacnusa* was present as a parasite of *Arrhinomyia*, it evidently killed the Tachinid in the larval stage of the latter, before the puparium was formed. As will be seen by the above list, the writer has found no previous record of *Dacnusa* sp. as a hyperparasite of TACHINIDAE.

(xii). ***Perilampus tristis*, Mayr** (Chalcididae: subfam. Perilampinae).

Three specimens of *Perilampus tristis*, Mayr, emerged from the French collections, on 1st, 2nd and 5th July 1930. To ascertain the host of this species, searches were made for the cocoons of the parasite in the cages concerned, some two months later.

In two cages no cocoon could be found ; in the third, a typical *Pristomerus vulnerator*, Panz., cocoon was found to contain another cocoon, dark in colour, and completely filling it. Both cocoons were defective, and contained no larval skins. Members of the genus *Perilampus* are known to be hyperparasites (Smith, 1912) ; and no other hyperparasites emerged in this cage. Hence it appears reasonably certain that, in this instance, the host of *Perilampus tristis*, Mayr, was *Pristomerus vulnerator*, Panz.

No host records of this species have been found ; but Parker (1924) states that he took specimens on the leaves of cork-oak, and that in captivity females oviposited on leaves of this tree.

(xiii). ***Perilampus laevifrons***, Dalm. (Chalcididae: subfam. Perilampinae).

One specimen of *Perilampus laevifrons*, Dalm., emerged from the French collections in a cage containing caterpillars, some of which were known to be parasitised by *Pristomerus vulnerator*, Panz., *Trichomma eneicator*, Rossi, and *Ascogaster quadridentatus*, Wesm. ; and if the species is assumed to be hyperparasitic, its host must have been one of these parasites. No cocoon of *Perilampus* was found. From the shipment of *Ascogaster quadridentatus* received from Yakima, Washington, nine individuals of *P. laevifrons* emerged ; and since no parasites other than *Ascogaster* and *Perilampus* emerged from this shipment, it appears almost certain that the *Ascogaster* was the host of *Perilampus* in this case. Unfortunately no search was made for cocoons of *Perilampus*.

This species has been recorded from the following hosts :—

Lepidoptera :

Argyroplote arbutella, Zell. (TORTRICIDAE) (Wagner, 1929).

Cydia pomonella, Linn. (TORTRICIDAE) (Sciarra, 1915).

Rhyacionia buoliana, Schiff. (TORTRICIDAE) (Feytaud, 1921).

Coleoptera :

Exocentrus (Exocentris) punctipennis, Muls. (LAMIIDAE) (De Gaulle, 1908).

It is probable that in all these cases *P. laevifrons* was actually a hyperparasite, attacking a primary parasite of the host mentioned ; although Smith (1912) mentions the possibility of species of *Perilampus*, in spite of a most complicated life-history, being able to develop as primary parasites of Lepidopterous hosts which feed within stems or galls, the *Perilampus* being thus protected from injury.

(xiv). ***Monodontomerus dentipes***, Boh. (Chalcididae: subfam. Toryminae).

This species has been recorded from the following hosts :—

A. As primary parasite :—

Hymenoptera :

Diprion pini, L. (TENTHREDINIDAE) (Sitowski, 1929).

D. simile, Hartig (TENTHREDINIDAE) (Hartley, 1923).

Lepidoptera :

Aporia crataegi, L. (PIERIDAE) (Stellwaag, 1924).

Dendrolimus pini, L. (LASIOCAMPIDAE) (Hartley, 1923).

Zygaena occitanica, Vill. (ZYGAENIDAE) (Rabaud, 1917).

B. As hyperparasitic :—

Hymenoptera :

Apanteles glomeratus, L. (BRACONIDAE) (Faure, 1925A).

Exochilum giganteum, Grav. (ICHNEUMONIDAE) (Seitner, 1927).

Pimpla spp. (ICHNEUMONIDAE) (Seitner, 1927).

Rhogas spp. (ICHNEUMONIDAE) (Seitner, 1927).

Tetrastichus xanthopus (CHALCIDIDAE) on *Dendrolimus pini*, L. (Seitner, 1927).

Theronia atalanta, Poda (ICHNEUMONIDAE) (Seitner, 1927).

Diptera :

Tachina sp. (TACHINIDAE) (Hoffmeyer, 1930 & 1931).

Of the records of *M. dentipes* as a primary parasite, two hosts in the above list are Hymenoptera, and it is not very unusual for insects which are normally hyperparasitic to attack Hymenopterous insects as primary parasites. One of the many parasites of *Aporia crataegi*, L., is *Apanteles glomeratus*, L. (Stellwaag, 1924), which is included above in the hosts of *M. dentipes*; and Seitner (1927) states that *dentipes* is a hyperparasite, and not a true parasite of *Dendrolimus pini*. There remains, of the Lepidopterous hosts, *Zygaena occitanica*; records of only seven parasites of this species have been found, none of which have so far been listed as hosts of *M. dentipes*. Nevertheless, analysis of the host list suggests that *Monodontomerus dentipes*, Boh., is a hyperparasite, except in cases where it attacks Hymenoptera as a primary parasite. *M. dentipes* occurs in all parts of Europe and in Russia. It is also found in the U.S.A., where it is stated to have been accidentally introduced from Europe (Hartley, 1923).

Three females emerged from one puparium of *Arrhinomyia tragica*, Mg. (Dipt., Tachinidae), contained within the pupa of its host, *Cydia pomonella*, collected at Elbeuf in September 1929.

(xv). **Eurytoma appendigaster**, Boh. (Chalcididae: subfam. Eurytominae).

This species has been recorded from the following hosts:—

Hymenoptera :

Apanteles glomeratus, L. (BRACONIDAE) (Paillot, Ferrière & Faure, 1924).

Hormius moniliatus, Nees (BRACONIDAE) (Vukasovich, 1928).

Microbracon terebella, Wesm. (BRACONIDAE) (Salt, 1931).

Microgaster globatus, Nees (BRACONIDAE) (Vukasovich, 1928).

Eurytoma appendigaster, Boh., has also been recorded by De Gaulle (1908) as a parasite of the following Cynipids: *Dryophanta* sp., *Rhodites* sp., *Xestophantes* sp.; but, according to Paillot, Ferrière & Faure (1924), parasites, referred to as *Eurytoma appendigaster*, Boh., from galls of Cynipids, are probably *E. rosae*, Nees, which is only distinguished from *appendigaster* by characters which are variable or difficult to see.

Fifteen specimens of *Eurytoma appendigaster*, Boh., emerged in the course of the work, of which 10 were males and 5 females; nine emerged from pupae of *Cydia pomonella*, L., the remainder from larvae received at the laboratory without cocoons; the species was only received from Elbeuf and Grignon. The host relationships of the larvae received without cocoons are unknown; of the nine *Eurytoma* from *Cydia* cocoons, seven were hyperparasitic. The cocoons in the two other cases were damaged, and the relation between the *Eurytoma* and the *Cydia* could not be determined. In five cases, the primary parasite was *Arrhinomyia tragica*, Mg. (Diptera, Tachinidae), and in two cases, *Trichomma enecator*, Rossi. Four parasitised *Cydia* pupae were examined, and show some variability on the part of the parasite.

A. The *Cydia* pupa contained a pupal skin and last-stage larval skin of *Eurytoma*, and a pupal skin of *Trichomma*; attached to the latter were five of the very characteristic eggs of *Eurytoma*. Inside the *Trichomma* pupa were the remnants of two larval skins of *Eurytoma*. In this case the *Eurytoma* female laid her eggs within the *Cydia* pupa, but outside that of *Trichomma*; only one of these eggs hatched, and the larva entered the *Trichomma* pupa, fed and emerged again into the space between the host and primary parasite pupa. Here the larva pupated and finally the adult emerged.

B. In this case the primary parasite was a larva of *Trichomma*, which had been attacked by a gregarious Chalcid, the eggs of which greatly resemble those of *Dibrachys cavus*, Wlk. (*D. boucheanus*, Ratz.), as figured by Parker (1924). In the *Cydia* pupa were found 19 of these eggs, and 23 larval skins believed to be first- and second-stage

Dibrachys; in addition there were found the skin of a mature *Trichomma enecator* larva, and the egg, the first, second and last-stage larval skins, and the pupal skin of *Eurytoma*. Owing to the bad state in which the *Trichomma* skin was found, it could not be decided whether the various larvae skins were within it, or between it and the *Cydia* pupa. Here the *Eurytoma* female attacked a host already parasitised and hyperparasitised; the *Eurytoma* larva killed the hyperparasitic larvae and completed its development.

C. Here the primary parasite was *Arrhinomyia tragica*, Mg. There was little remaining of the Dipterous pupa within the puparium, which contained larval and pupal skins of a female *Eurytoma*.

D. In this case an *Arrhinomyia* puparium was found to contain the somewhat shrunken remains of the Tachinid, which, when attacked, was apparently almost ready to emerge. In the puparium were also the egg, last-stage skin, and pupal skin of *Eurytoma*, and six eggs and one first-stage skin, believed to be *Dibrachys* sp., similar to those found in Case B. The *Eurytoma* which emerged was a male.

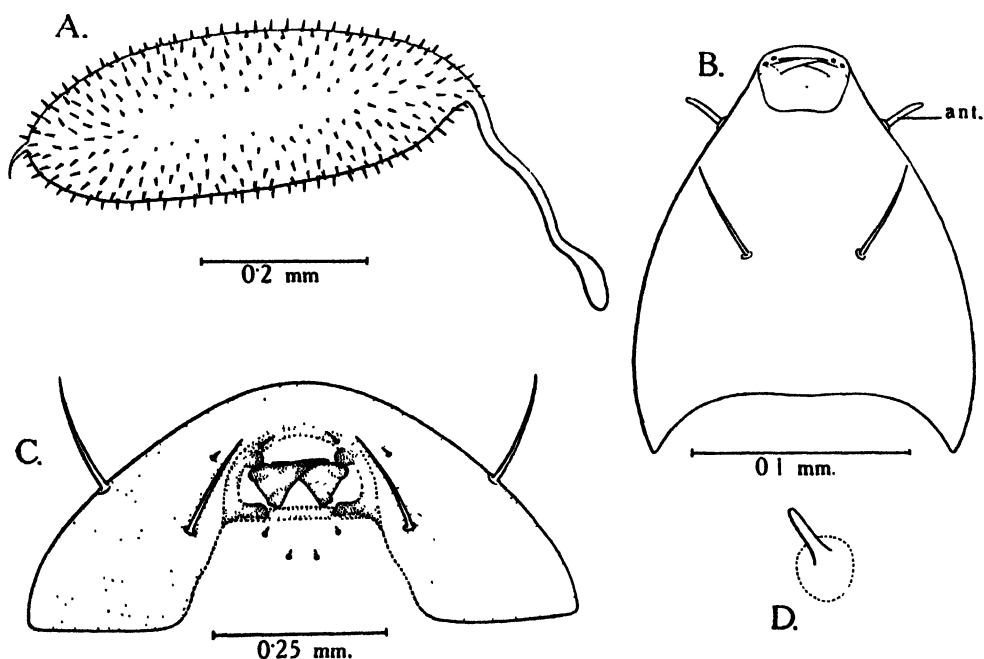


Fig. 13. *Eurytoma appendigaster*, Boh.; A, egg; B, head of 1st stage larva; C, head of full-grown larva; D, antenna of mature larva (to same scale as B); ant, antenna.

Thus, *Eurytoma appendigaster*, Boh., attacks two parasites of the Codling Moth. When *Trichomma enecator* is the primary parasite, the egg is laid outside the *Trichomma* larva, and the hyperparasite larva enters the *Trichomma* larva to feed, and leaves it to pupate. When *Arrhinomyia tragica* is the primary parasite, development of *Eurytoma* from egg to adult takes place within the puparium of *Arrhinomyia*. There was a striking difference in the amount of the host unconsumed in cases C and D; this may perhaps be partly due to the fact that the *Eurytoma* which emerged in the first of these two cases was a female, and in the second a male, males being considerably smaller than females. But even a female *Eurytoma* is much smaller than an adult *Arrhinomyia*, and their relative volumes may be estimated as 1 : 5. It seems probable that, in case D, the *Arrhinomyia* was in a much later stage of development when

attacked than in case C. Further information is desirable as to the stage in which *Trichomma* is normally attacked by *Eurytoma*; probably variation occurs here also, and either the larval or pupal stage may be attacked. The hyperparasite which occurred with *Eurytoma*, and was killed by it, was almost certainly *Dibrachys* sp.; the eggs were very similar to those figured by Parker, and the larvae also were similar. Further, the only other gregarious Chalcid bred from *Cydia* pupae was *Monodontomerus dentipes*, Boh., which was much less common; the eggs of a species of *Monodontomerus*, figured by Parker, have similar ornamentation to that of the eggs found, but are of different shape.

The egg of *Eurytoma appendigaster*, Boh., is very similar to that of *E. rosae*, figured by Parker (1924). It is approximately 0.5 mm. long, by 0.2 mm. in width, with a short pedicel at one end, and a pedicel about 0.3 mm. long at the other; the surface of the egg is covered with short, strong spines. The head of the first-stage larva also resembles that of *E. rosae*, being different in shape and in the area sclerotized from *E. dentata*, as shown by Parker. The elongate head is heavily sclerotized, with a rounded mouth-opening on the anterior ventral surface. The mandibles are elongate and transverse; not so strongly curved as are those of *E. rosae*. Anterior to the mandibles, on the ventral edge of the clypeus, are two pairs of low, rounded papillae. The antennae are situated on the dorso-lateral areas of the head. On the ventral surface of the head are two strong elongated spines. No other sensory structures are visible. On the ventral portion of the first abdominal segment are a pair of low, rounded bosses. Each body segment bears about four setae, from 0.06 to 0.1 mm. in length; the specimens examined were somewhat damaged, but the setae are apparently in four rows along the body. The last-stage larva has a head-capsule highly sclerotized in the lateral areas. Two points of articulation for the mandibles are present on each side; joining the anterior pair is a narrow sclerotized strip across the clypeus. The posterior pair are joined by a strip of cuticle, in which the degree of sclerotization varies in different specimens. The papilla-like antennae are on the dorsal side of the head. There is a small seta on each side of the clypeus, near the anterior mandibular articulation; another pair are situated to the lateral side of the articulation. On the unsclerotized labial area are two pairs of small setae. There are four pairs of large setae, from 0.15 to 0.18 mm. in length, on the head; two pairs are shown in fig. 13 C, the other two pairs are on the dorsal surface of the head.

(xvi). **Eupelmus urozonus**, Dalm. (Chalcididae: subfam. Encyrtinae).

This species has been recorded from the following hosts:—

Hymenoptera:

- Angitia punctoria*, Rom. (ICHNEUMONIDAE) (Parker, Vance, Smith, and Gamkrelidze, 1929).
- Goniozus claripennis*, Först. (BETHYLIDAE) (Vukasovich, 1924A).
- Nematus viminalis*, L. (TENTHREDINIDAE) (Russo, 1926).
- N. gallicola*, Steph. (TENTHREDINIDAE) (Russo, 1926).
- Aphilothrix ferruginea*, Först. (CYNIPIDAE) (Russo, 1926).
- Andricus terminalis*, F. (CYNIPIDAE) (Russo, 1926).
- Aphelonyx cerricola*, Giraud (CYNIPIDAE) (Russo, 1926).
- Cynips kollari*, Htg. (CYNIPIDAE) (Russo, 1926).
- C. terminalis*, F. (CYNIPIDAE) (Russo, 1926).
- Dryophanta agama*, Htg. (CYNIPIDAE) (Russo, 1926).

Coleoptera:

- Apion pubescens*, Kirby (CURCULIONIDAE) (Russo, 1926).
- A. salicis*, Gyll. (CURCULIONIDAE) (Russo, 1926).
- Cassida filaginis*, Petr. (CASSIDIDAE) (Russo, 1926).
- Hylesinus vestitus*, Muls. & Rey (SCOLYTIDAE) (Russo, 1926).
- Scolytus amygdali*, Guér. (SCOLYTIDAE) (Russo, 1926).

Lepidoptera :

- Aporia crataegi*, L. (PIERIDAE) (Stellwaag, 1924).
Coccyx strobilella, L. (TORTRICIDAE) (Russo, 1926).
Etiella zinckenella, Tr. (PYRALIDAE) (Shchegolev & Mamonov, 1929).
Grapholitha strobilella, L. (TORTRICIDAE) (Russo, 1926).
Polychrosis botrana, Schiff. (TORTRICIDAE) (Vukasovich, 1924).

Diptera :

- Carpomyia incompleta*, Beck. (TRYPETIDAE) (Silvestri, 1916).
Dacus oleae, Gmel. (TRYPETIDAE) (Silvestri, 1916).
Myopiles limbardae, Schin. (TRYPETIDAE) (anonymous, 1925).

According to De Gaulle (1908) *E. urozonus* is similar in habits to *E. degeeri*, Dalm., which he describes as omnivorous ; he also states that *urozonus* is a hyperparasite of *Eurytoma* and of *Microgaster*.

One specimen of *Eupelmus urozonus*, Dalm., was reared from a larva found in a *Cydia* cocoon at Elbeuf ; unfortunately this larva was forwarded by the Field Agent without the remains of its host, so that its relationship with the Codling Moth could not be determined. The only host in the above list which has been met with in connection with the Codling Moth is *Eurytoma* ; since Elbeuf is one of the two localities from which *Eurytoma appendigaster*, Boh., was received, it is possible that this species was the host of *Eupelmus* in this case. However, in view of the great variety of the recorded hosts, it is quite possible that *E. urozonus* was a primary parasite of *C. pomonella*. The single specimen reared lived for 74 days at room temperature.

(xvii). ***Dibrachys affinis***, Masi (Chalcididae : subfam. Pteromalinae).

This species has been recorded from the following hosts :—

Hymenoptera :

- Anilastus ebeninus*, Grav. (ICHNEUMONIDAE) (Faure, 1925A).
Apanteles glomeratus, L. (BRACONIDAE) (Vukasovich, 1924B).

Diptera :

- Calliphora erythrocephala*, Mg. (CALLIPHORIDAE) in laboratory (Vukasovich, 1924B).
C. vomitoria, L. (CALLIPHORIDAE) in laboratory (Vukasovich, 1924B).

Lepidoptera :

- Hyponomeuta* sp. (TINEIDAE) in laboratory (Vukasovich, 1924B).
Polychrosis botrana, Schiff. (TORTRICIDAE) (Vukasovich, 1924B).
Sitotroga cerealella, Ol. (TINEIDAE) in laboratory (Vukasovich, 1924B).
Sparganothis pilleriana, Schiff. (TORTRICIDAE) in laboratory (Vukasovich, 1924B).

Specimens of *Dibrachys affinis*, Masi, were reared in the laboratory from pupae of *Cydia pomonella*, collected at Elbeuf and Grignon, several parasites emerging from each host pupa.

(xviii). ***Dibrachys cavus***, Wlk. (Chalcididae : subfam. Pteromalinae).

This parasite has been recorded from a wide range of hosts ; in the card-index of the Farnham House Laboratory are records of its occurrence on :—11 species of Ichneumonidae ; 16 species of Braconidae, including *Ascogaster carpocapsae*, Vier. (Cox, 1932) ; 2 species of Chalcididae ; 3 species of Tenthredinidae ; 1 species of Eulophidae ; 1 species of Apidae ; 9 species of Tachinidae ; 34 species of Lepidoptera of 11 families, including *Cydia pomonella* and *C. molesta* ; 3 species of Coleoptera ; and 1 species of Neuroptera.

Dibrachys cavus, Wlk., was one of the most common parasites of Codling Moth pupae collected at Grignon and Elbeuf. The host pupae were in various stages of

development ; in one case *D. cavus* emerged from a pupa containing a moth just about to emerge. *D. cavus* was also present as a hyperparasite of puparia of *Arrhinomyia tragica*, Mg. (Dipt. TACHINIDAE) in pupae of *Cydia pomonella*, and as a hyperparasite of *Ephialtes extensor*, Tasch. ; and as stated in section (xiv) above, was suspected to be a hyperparasite of *Trichomma enecator*, Rossi, although no specimens were reared from this parasite. *Dibrachys cavus* was bred in the laboratory on pupae of *Cydia pomonella*, thus confirming the observation of Sciarra (1915).

(xix). ***Arrhinomyia tragica*, Mg. (Diptera, Tachinidae).**

A. tragica has been recorded from the following hosts :—

Lepidoptera :

Epiblema semifuscana, Steph. (TORTRICIDAE) (Faure, 1923).

Cydia pomonella, L. (TORTRICIDAE) (Baer, 1920 & 1921).

Hypsolophus persicellus, F. (TINEIDAE) (Faure, 1923).

Tortrix viridana, L. (TORTRICIDAE) (de Seabra & dos Santos Hall, 1924).

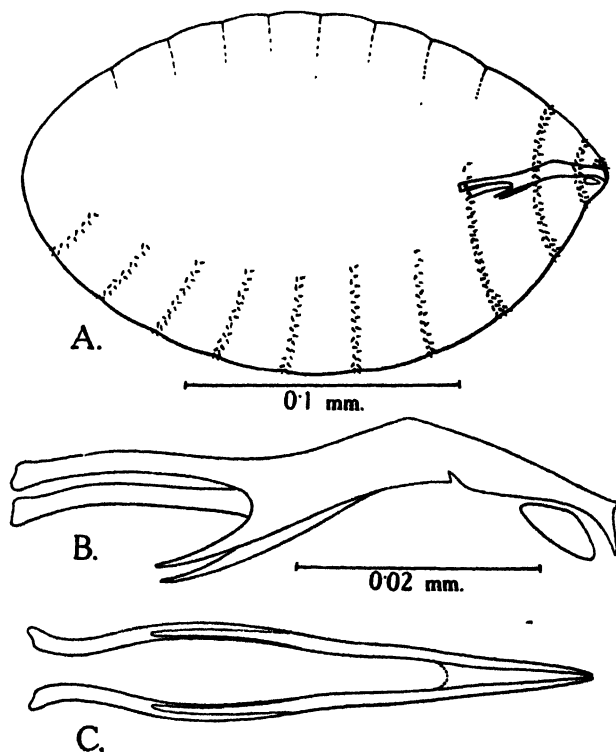


Fig. 14. *Arrhinomyia tragica*, Mg. : A, larva in egg ; B and C, mouth-hook of 1st stage larva, lateral and ventral views respectively.

Arrhinomyia tragica was one of the most abundant of the parasites of the Codling Moth found in France ; it occurred in all regions from which collections were made, with the exceptions of Beauvais (Oise), Toul (M. et M.), and Annecy (Hte. Sav.).

Only small collections of larvae were made at these localities ; if larger collections had been possible, *A. tragica* might have been found to be present.

Some of the *Cydia* pupae collected were split on the ventral surface, at the base of the wing-cases, and through the split were visible the spiracles of an *Arrhinomyia* puparium. By error, the majority of the puparia were discarded ; the few retained

were found to be either dead or hyperparasitised. *Arrhinomyia* adults emerged in the spring from collections of *Cydia* larvae; in these cases, the empty puparia were subsequently found in *Cydia* larvae, with the spiracles protruding from the ventral surface of the abdomen. In all cases, the anterior end of the puparium was directed towards the head of the host. It appears that when the host is a *Cydia* larva, which, if unparasitised would pupate and give rise to an adult during the same season, the host is not killed until after pupation. When the host is a larvae which hibernates, the parasite passes the winter as an egg or immature larva, resumes growth in the spring more quickly than the host, and assumes the puparium form before the time of pupation of the host.

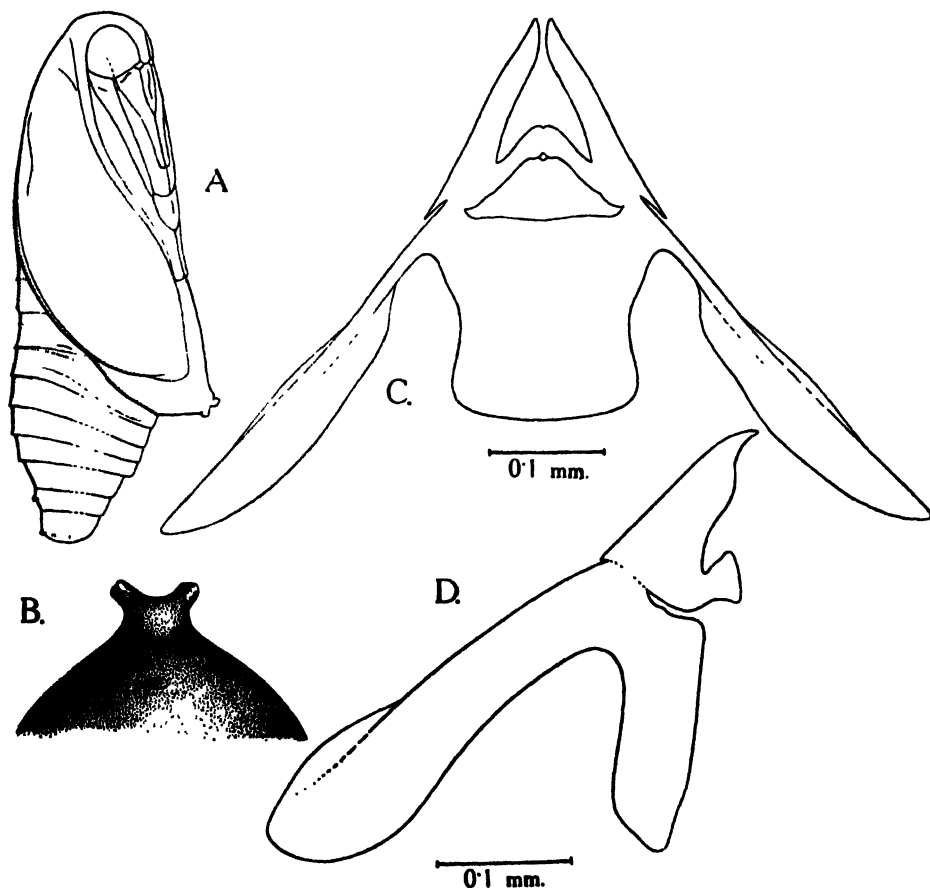


Fig. 15. *Arrhinomyia tragica*, Mg : A, *Cydia pomonella* pupa, containing *Arrhinomyia* puparium ; B, ventral view of posterior end of puparium, showing stigmatic tubercles and anal opening ; C and D, mouth-hook of mature larva, ventral and lateral views respectively.

Prolonged attempts were made to breed *Arrhinomyia* in the laboratory. Females were supplied with water and sugar-lumps; and apples, with and without Codling Moth eggs, and Codling Moth larvae in cocoons were put in the cages. The Tachinid laid eggs in the calyx of an apple on one occasion, and once on the skin of an apple away from the calyx; eggs were also laid on the body of a dead male *Arrhinomyia*, and twice a cluster of eggs was found on the floor of the cage. These eggs contained larvae, the mouth-hooks of which could be plainly seen, the eggs being less chitinised than those of Tachinids that lay eggs on leaves usually are. No eggs hatched,

although they were kept and observed for several weeks. *Cydia* larvae were put on apples on which *Arrhinomyia* eggs had been laid, to observe if the eggs were eaten; but the caterpillars entered the apples without taking any notice of the eggs, other than in avoiding them. Indeed, a comparison of the relative sizes of the *Arrhinomyia* eggs and the mouth-parts of the newly-hatched *Cydia* larvae makes it appear unlikely that it would be possible for the larvae to swallow the eggs. The fact that fertilised eggs laid did not hatch suggests that either the eggs are swallowed by their host before hatching, or that in some way the oviposition site was unsuitable. The way in which *Arrhinomyia* effects the parasitism of the *Cydia* larvae thus remains undiscovered.

The egg of *A. tragica* is colourless and transparent; the surface is rugose, the markings being round and close-set. The larva is plainly visible through the chorion. The egg is 0.21 to 0.22 mm. in length and about 0.13 mm. in greatest diameter; the larva almost fills the egg (fig. 14, a). The mouth-hook of the larva is 0.05 mm. in length and is densely sclerotized. A pair of sclerotized plates in the wall of the oral cavity lie at the sides of the mouth-hook. Immediately above the mouth is a cluster of short, broad spines; there are two girdles of spines surrounding the body behind the mouth, and eight bands of spines on the ventral surface. Both girdles and bands are composed of spines irregularly arranged, the spines being more numerous close to the median ventral line than elsewhere. The puparium is about 6 mm. in length, by 2.5 mm. in greatest width, and red-brown in colour. It is rounded anteriorly and somewhat flattened ventrally. In the posterior ventral region, immediately behind the anus, is a protrusion in the form of a cone with a rounded apex, bearing the stigmatic tubercles; the tubercles diverge at an angle of 60° from each other, and the distance between their bases is about equal to their length. The buccopharyngeal armature of the third-stage larva was obtained by dissection from the puparium. The parts are fused together and little trace of articulation remains; two prominent mandibles occur. In all specimens examined, two sclerotized plates, semi-circular in shape, occur between the mandibles, and numerous short spines; the nature of these plates is uncertain, but they presumably are part of the armature of the mouth of the larva, which has been drawn in at the time of formation of the puparium.

(xx). *Exorista westermanni*, Zett. (Diptera, Tachinidae).

A single specimen of the species was reared from the collection of larvae from Herblay (S. et O.); and, from information supplied by the present writer, was recorded as a parasite of *Cydia pomonella* by Thompson (1930, p. 83). However, when subsequently a search was made for the puparium and host skin of this parasite, these could not be found; consequently, while *E. westermanni* was most probably a parasite of the Codling Moth, its host is not definitely known. This species has not been recorded, prior to Thompson's paper, as a parasite of *Cydia pomonella*; Baer (1920 & 1921) records it as a parasite of two NOCTUIDAE, *Calymnia affinis*, L., and *Cucullia prenanthis*, Boisd.

6. Conclusions.

As stated above, in section 4 of this paper, the percentage of parasitism of internal parasites has been calculated from the relative numbers of parasites and moths emerging in the spring, and of *Ephialtes*, from the relative numbers of parasite cocoons and host larvae collected. The percentage of parasitism was found to be very low; the percentage of total parasitism of *Cydia* larvae was highest (25.75 per cent.) at Toul (M. et M.) and lowest in the Paris Region in 1928-29 (1.37 per cent.). The highest percentages recorded for the common species of parasites were as follows:—

<i>Pristomerus vulnerator</i> , Panz. ...	14.29 per cent.	Toul (M. et M.) 1929-30.
<i>Trichomma enecator</i> , Rossi ...	3.11 „	Lyons Region (Rhône) 1929-30.
<i>Ascogaster 4-dentatus</i> , Wsm. ...	5.71 „	Toul (M. et M.) 1929-30.
<i>Ephialtes extensor</i> , Tasch. ...	11.0 „	Lyons Region (Rhône) 1929-30.
<i>Arrhinomyia tragica</i> , Mg. ...	2.63 „	Rennes (I. et V.) 1929-30.

Generally speaking, the more apple trees and Codling Moth there were in any locality, the lower was the percentage of parasitism. As has been stated, many *Cydia* larvae which, by their size, would be judged to contain *Ascogaster*, died after collection, before re-making their cocoons; it is impossible to estimate their number accurately, but in some collections 3–5 times as many of such larvae died, as there were *Ascogaster* emerged. Again, the percentages of parasitism by *Ephialtes* are probably underestimated in some cases, owing to the death of immature larvae and eggs in the field; and two generations of *Ephialtes* females attack hibernating *Cydia* larvae, in the autumn and in the spring. From the numbers of parasitised puparia found, it seems probable that *Arrhinomyia* parasitises a larger percentage of larvae in earlier generations than in the hibernating generation.

All these considerations are, however, insufficient to show that *Cydia pomonella* is to any very large extent kept in control by parasites of the larva in France. Other controlling factors are: A, egg parasites; B, predators of the larvae; C, predators of the moths; D, disease; and E, control through human action. Of these, no information has been gained with regard to A and C. There is no doubt that parasites of the genus *Trichogramma* and other genera occur and give some measure of control, and that *Cydia* moths are eaten by bats and birds. There is no evidence showing that disease is an important controlling factor under natural conditions. The fungus, *Beauveria globulifera* (Speg.) Pic., killed a large number of the larvae collected at Elbeuf, but these larvae were under highly unnatural, crowded conditions. The larvae were found to avoid the damp, moss-grown parts of the tree-trunks; this tendency would be unfavourable to fungus diseases. The only predators discovered in France were twelve Coleopterous larvae, probably of the family MALACHIIDAE; these were stated by the Field Agent to be predacious on *Cydia* pupae. They were supplied with pupae at the laboratory, but only three of them fed at all, and all died without completing their development. Birds are common predators of the larvae, although no observations on this point were received from France. In an experiment at Farnham Royal, one hundred *Cydia* larvae in cocoons in strawboard sections were pinned to the bark of apple trees, in an endeavour to secure oviposition by parasites. In spite of an arrangement of wire netting over them, to keep birds away, all were eaten within a few days; some young robins were observed near the trees, and it is presumed that these birds were able to pass through the wire netting. In every case, a small hole had been punched in the strawboard and the larvae removed through this.

There remains, of the controlling factors listed above, control through human action. Deliberate control measures, such as spraying or banding, are uncommon in the areas where the collections were made. But two other factors must have a great effect on the survival of the Codling Moth. First, where the soil under the trees is cultivated, many larvae which have made cocoons in the soil, or in rubbish at the base of the tree, must be destroyed. Second, a very large number of larvae must be removed with the fruit. In the case of eating apples, there is a possibility of moths which emerge in packing or storage sheds finding their way back to the orchard; but when the apples are used for cider making, the larvae would be destroyed in the process.

The figures given show that parasites of the larvae are by themselves insufficient to control *Cydia pomonella* in France. It appears that three major factors of control are present, as follows: 1, parasites of the larvae; 2, predators (*i.e.*, birds) of the larvae; 3, removal of larvae with the crop; each of these factors being of comparable importance to one another. These facts make less hopeful, than might otherwise have been the case, the shipment of parasites of the Codling Moth to countries into which the host has been introduced. Parasites of the genus *Ephialtes*, or allied genera, have been introduced into California from Spain, and from California into South Africa (Cushman, 1913; Lounsbury & Faure, 1918), apparently with little success. Where trees are banded with sacking and the sacking removed to destroy *Cydia*

larvae, *Ephialtes* larvae would also be killed ; this accounts in part for the lack of success with these parasites. Another parasite, *Ascogaster quadridentatus*, has been shipped from Farnham House Laboratory to New Zealand and South Africa ; no reports have been received as to the progress of the parasite in these countries. It has been recorded (Official Record, U.S. Dept. Agric., Washington, 7.iii.28) that *Ascogaster carpocapsae* parasitised 31 per cent. of Codling Moth larvae at Yakima, Washington, in 1927 ; stocks of this parasite are being distributed throughout apple-growing districts of the U.S.A. Of the other parasites found in France, *Pristomerus*, *Trichomma* and *Arrhinomyia* could not be bred in the laboratory and were not present in sufficient numbers for a shipment of collected material to offer much chance of success. *Cryptus sexannulatus*, Grav., and *Spilocryptus incubitor*, Ström., were rare in France ; they might be successful in other countries, but would suffer from the same disadvantage as *Ephialtes*, in that parasite larvae would be destroyed in sacking-bands. No other parasites suitable for shipment were found. *Ascogaster* remains the most hopeful species for shipment ; it is hoped that the species will be successful in South Africa and New Zealand. If this should not be so, further attempts to utilise *Ephialtes extensor* might be desirable, in spite of the little success obtained in the past with this or similar allied parasites ; and, if available, *Cryptus sexannulatus*, Grav., and *Spilocryptus incubitor*, Ström., are worth a trial.

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8. Summary.

1. Collections of *Cydia pomonella* were made in France in 1928 and 1929-30.
2. The numbers of moths and parasites that emerged from the collections are given.
3. The biology and host-lists of the parasites are dealt with, and information on the larval anatomy is given.
4. Low percentages of parasitism of the larvae were found, and it is concluded that predacious birds, and the removal of larvae with the crop, must be important factors in the control of the Codling Moth in France.

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THE MALES OF *LEPTOCONOPS TORRENS*, TNS., AND *L. KERTESZI*, KIEFF.

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For years the territory adjacent to the rivers on the floors of the Sacramento and northern San Joaquin valleys in California has been deluged each spring with hordes of fiercely biting "black gnats." Certain areas locally known as "black alkali" locations seemed to form the foci from which these pests were blown by winds over wide areas, constituting such a pest in some seasons that agricultural field work was brought to a standstill and even town dwellers were driven indoors until nightfall. The bites are extremely irritating, causing nodular, inflamed swellings that itch persistently for several days or even weeks. In some individuals, particularly those inclined to be stout, the swellings caused by the bite become vesicular, rupture, and produce a moist open lesion that "weeps" a serous exudate for weeks, finally healing with a definite red scar. The insects insinuate themselves beneath the clothing and apparently prefer to bite at some point where their progress is impeded, such as around the hat band, at the belt line, or where the sleeves are closely rolled against the arms, and at the shoe tops. The usual repellents that are effective against mosquitos are of little use against these insects, the only casualties noted being the ones that were actually trapped or drowned in the oily applications used.

For some time it was casually supposed by entomologists and laymen alike that the insects were "true black gnats" or Simuliids, but the first microscopic attention devoted to them revealed that they were Chironomids of the genus *Leptoconops*. Specimens forwarded to Washington for identification were provisionally determined as *Leptoconops torrens*, Townsend, and *Leptoconops kerteszi americanus*, Carter.

Carter* in 1921 presented an admirable paper outlining the known information concerning the genus and describing several new species. This paper did a great deal to straighten out the conflicting descriptions and made it possible for the general worker to consider specimens of the genus intelligently. In 1926 Hoffman† described two new species of the genus, one of which, *L. carteri*, has as a type locality the same area in which we have been working and our specimens agree very closely with this published description.

Concerning the males of this genus, very little authoritative information is available. Weiss' description‡ of the male of *L. kerteszi* is so strikingly at variance with other members of the genus that one is led to believe that the material at hand was either mistakenly associated or a particularly poor preparation. Carter's

* Carter, H. F. A revision of the genus *Leptoconops*, Skuse.—Bull. Ent. Res. 12 1921 pp. 1-28.

† Hoffman, W. A. Two new species of American *Leptoconops* (Diptera, Chironomidae).—Bull. Ent. Res. 17 1926 pp. 133-136.

‡ Weiss, A. *Mycterotypus laurae*, n. sp., Chironomide nouveau du Sud Tunisien.—Arch. Inst. Pasteur Tunis, 1912, pp. 25-32.

description (*loc. cit.*) of the male of *L. torrens* was from a slide preparation that failed to show the characters of the wings or terminalia. Noè has described§ the male of *L. bezzii* and Hoffman (*loc. cit.*) has described that of *L. hondurensis*, but the other attempts at descriptions of males have been based on imperfect material and are consequently lacking in many essential points.

It may be of interest to record our methods of capturing males. Except in one case with *L. kerteszi*, when we were fortunate enough to discover a dancing swarm of males, the usual procedure was to offer ourselves as bait to the swarms of females and then enter a closed motor car. The females and any males that were with them would then fly to the windows where they could be captured by sucking them into an aspirator. In many cases the males would come to the outside of the windows when there were numerous females on the inside and could be sucked off in a similar manner. They are extremely easy to identify by their stiffly plumose antennae which project forward as rigid black cones.

Although we have not seen Townsend's types of *torrens*, we fail to find any differences in the descriptions which would justify the erection of *carteri* as a species separate from the former. Carter's redescription of *torrens* varies from our specimens only in size, which we found to vary among individuals, and in noting that the spermathecae were subspherical (0.036) whereas in our specimens these organs are distinctly ovoid (0.044 × 0.03). Although Townsend did not mention specifically the shape of the spermathecae as such, his figure shows them to be distinctly ovoid. In addition, we have had the opportunity, thanks to Dr. J. M. Aldrich, to compare our specimens with females of *torrens* from Uvalde and Dallas, Texas, which seem to be identical in every respect. A male labelled *L. torrens*, Tns., Las Vegas, New Mexico, has the genitalia badly mutilated, but from our study of a large number of prepared genitalia of our species it is possible to recognise all the essential characteristics and substantiate the fact that this male, taken from a source near the type locality, is identical with the California members of the species taken from the type locality of *carteri*, Hoffman. We consequently feel justified in suggesting the submergence of *carteri* and give herewith our description of the male of *torrens*, Tns., based on specimens taken in Yolo County, California.

***Leptoconops torrens*, Tns.**

♂. Length (foretip of thorax caudad), 2.1 mm.; length of wing, 1.2 mm.; width of wing, 0.4 mm.

Head black, nude except for supraorbital bristles which continue across the head between the eyes. Antenna 15-segmented, basal portion filling most of the antennal excavation, which is sparsely clothed with microchaetae, basal segments ring-like and contiguous over the frons; torus (second segment) circular, inflated, "doughnut"-shaped, its surface reticulated and with almost imperceptible microchaetae; third segment funnel-shaped (0.225 mm.); 4th-12th segments subspherical (0.15 mm. long) with long, stiff, forward-projecting hairs arising from a median whorl; 13th-15th progressively more elongate, each with a proximal bulb for hair insertion and slender beyond, the last segment clavate. *Palpi* slender, third segment slightly swollen at a point just beyond the middle, sensory pit inconspicuous, fourth segment uniform, slightly less than three-fourths as long as the third. *Proboscis* heavily chitinized, labella prominent, mandibles and maxillae absent, hypopharynx and labrum with teeth reduced to hair-like spines. Eyes reniform, separated at the vertex and on the ventral margin by a distance equal

§ Noè, G. Un nuovo genere appartenente alla famiglia Chironomidae.—Rend. R. Accad. Lincei (5) 15 1905 pp. 114-120.

to two-fifths the width of the head. *Frons* reduced to a small elevated area between and above the eyes which is connected with the clypeus by a mere strand that is overlapped by the basal segments of the antennae. *Clypeus* roughly triangular, the apex pointing dorsally, central portion raised, bearing four bristles, the dorsal pair in a median vertical line and the lower pair in a horizontal line; the depressed lateral portions each with four bristles.

Thorax black, mesonotum sparsely clothed with delicate microchaetae and scattered hairs; scutellum evenly rounded, with three single hairs on each side. *Legs* uniformly dark; metatarsus of fore- and mid-legs equal in length, those of hind legs slightly longer; all metatarsi clothed with strong bristles, those of mid- and hind-legs with stouter differentiated ones distally; claws equal and simple. *Wings* whitish, uniformly clothed with microtrichiae, and three times as long as wide. Venation as in fig. 1, a.

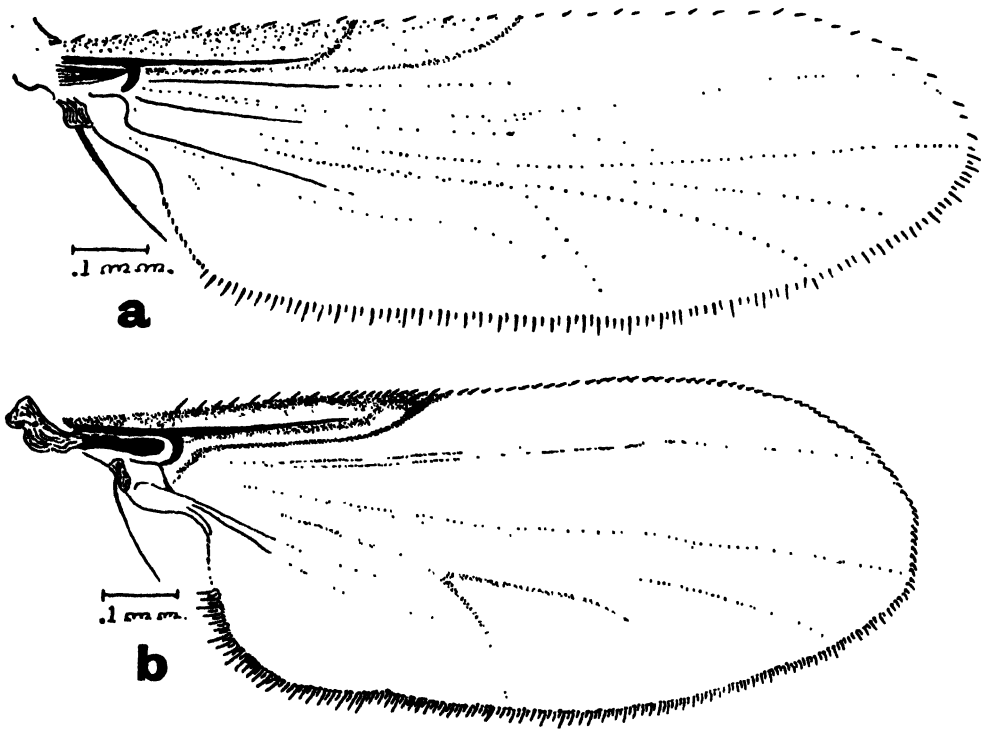


Fig. 1. *Leptoconops torrens*, Tns.: a, wing of *♂*; b, wing of *♀*.

Abdomen dark brown, uniformly clothed with microchaetae and a few long slender hairs. *Terminalia* (fig. 2): *Ninth tergite* expanded into a blunt triangle with down-turned sides which cup the distal and lateral sides; on the distal dorsal margin are two small setiferous lobes, one on either side of the median line and proximad a series of long stout setae; the posterolateral flanges that are bent ventrally each support a stout finger-like rod with a semicircular base and at the caudal end on the ventral surface is a pair of fleshy lobes, each bearing two stout bristles and lying directly below the smaller dorsal ones mentioned above. *Gonostyles* (side-pieces) consisting of a basistyle approximately twice as long as wide and a dististyle approximately half as long as the basistyle; basistyle with a dome-like

basal lobe and many stout bristles longer on the outer sides; dististyle swollen at the base but tapering rapidly to the tip, which from the ventral aspect appears bifid but dorsally is shown to consist of a ventral prolongation of the dististyle to form one of the tips, while the other is formed by a digit-like claw articulated dorsally and subapically. *Ninth sternite* regularly band-shaped. *Aedeagus* columnar. "Harpagones" of authors, which are probably the paraprocts, the chitinous supporting structures of the anal segment, arise near the outer edges of the bases of the gonostyles and project mediad and caudad in three sections, the two basal sections heavily chitinized and characteristic, but the third section, which lies above and caudad of the tip of the aedeagus, weakly chitinized and often indistinguishable from the weakly chitinized portion of the proctiger, the base of which it seems to encircle.

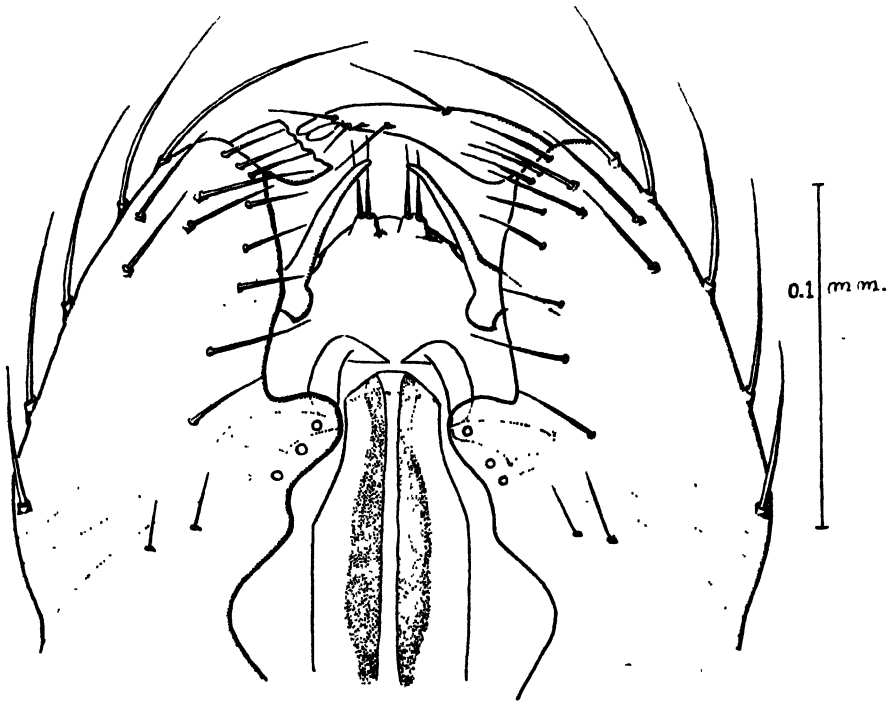


Fig. 2. *Leptoconops torrens*, Tns.: terminalia of ♂.

At Bodega Bay, Sonoma County, California, in a district made up of wind-swept hills, salt marsh, dune, and beach, another species of *Leptoconops* was taken throughout the summer. This species is undoubtedly referable to *L. kerteszi*, as there are no constant differences between it and the cotypes of *L. kerteszi americanus*, Carter, seen at the National Museum. Carter established the variety *americanus* on a variation of venation and the spherical shape of the spermathecae of the Utah specimens, as contrasted with the obovate spermathecae of the Mediterranean forms. The female wing of the California specimens (fig. 3, b) tends to unite characters of both Mediterranean and Utah forms as figured by Carter, and one cotype of *americanus* deposited in the National Museum shows one spermatheca spherical and the other obovate, while another shows both spermathecae obovate. One striking point that we have not seen mentioned in other descriptions is the brilliant scarlet stigma

of the female wing. This is not constant, however, a few specimens having the stigma orange-red, while others show it pale yellow or practically colourless.

The examination of males from the Mediterranean region may justify the separation of our form from *kerteszi kerteszi*, but in the absence of this material we give herewith the description of the male from material taken at Bodega Bay, California, as that of *L. kerteszi*, Kieff.

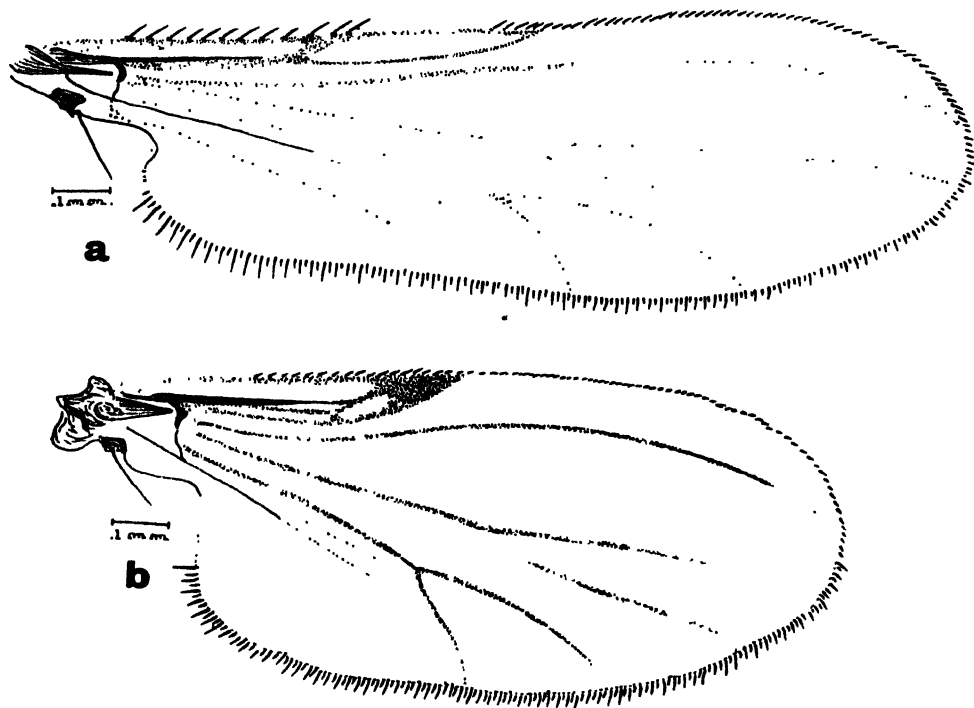


Fig. 3. *Leptonocops kerteszi*, Kieff.: a, wing of ♂; b, wing of ♀.

***Leptonocops kerteszi*, Kieff.**

♂. Length (foretip of thorax caudad), 2.2 mm.; length of wing, 1.62 mm.; width, 0.525 mm.

Head as in female except that the *frons* is reduced to a small triangle lying above and between the antennal excavations with an almost imperceptible strand connecting it with the clypeus between the practically contiguous antennae. Clypeus reduced to a small triangle with its apex directed upward between the antennae. *Antennae* 15-segmented, with first segment ring-like, nude; second segment much enlarged (0.135 mm. in diameter) with convex sides and a roundedly sunken centre, its cuticula reticulated and clothed with microchaetae; third segment funnel-shaped; fourth to fifteenth each with a whorl of very long stiff hairs projecting forward, the basal segments sub-globose (the fourth twice as wide as long) but gradually becoming more elongate (beyond the eighth longer than wide); fourteenth 0.375 mm. long, with slight swelling for inception of hair-whorl; fifteenth segment 0.9 mm. long, slightly swollen to the hair-whorl, clavate distad, with numerous hairs and sensory pits. *Palpi* with third segment slightly swollen before the middle, sensory pit small, fourth segment slightly shorter than third. *Mouth-parts* reduced, no apparent armature; labella prominent, fleshy.

Thorax as in the female. Fore metatarsus with an unequal pair of spine-like setae apically and distally and a row of three centrally located on the posterior margin; mid metatarsus with an apical and distal pair and hind metatarsus with none except distally. *Wings* (fig. 3, *a*) decidedly longer and slightly narrower than those of female (1.65×0.525 mm.). Orange or red colour absent in stigmal area. *Terminalia* (fig. 4): basistyles short and stout, with a basal lobe and apical condyles for articulation with the dististyles, which are markedly swollen just before the middle, narrowed at the tip and bearing two articulated claws each; ninth tergite

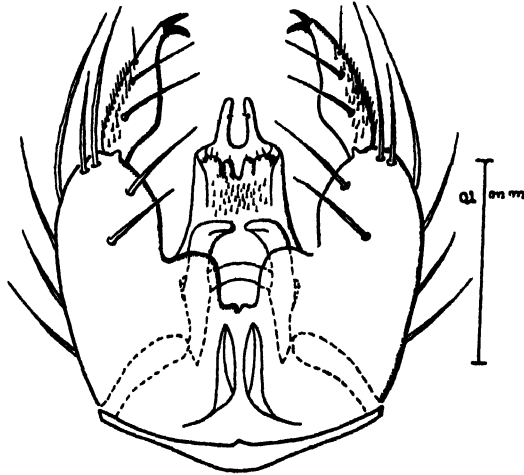


Fig. 4. *Leptoconops kerteszi*, Kieff., terminalia of ♂.

with two median digits, the lateral portions bent ventrally to form a partly closed cylinder in which is found a fleshy mass (anal segment?) terminating distally in four small setiferous lobes, rugose ventrally with many microsetae; aedeagus two simple concave valves; chitinous thickenings (paraprocts) originating at the base of the basistyles joined by a dorsal arch and of characteristic shape basally but obscure distally; ninth sternite narrow, with a median point.

ON THE ECOLOGY OF ACRIDIDAE NEAR LAKE CHAD.

By F. D. GOLDING, M.A., F.R.E.S.

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I. Introduction.

In early December 1929, many swarms of the Migratory Locust, *Locusta migratoria migratorioides*, R. & F., entered the south-western corner of Nigeria from Dahomey. It was then nearly 30 years since Nigeria had experienced a general infestation by locusts.

During the three months preceding the beginning of the *Locusta* invasion four swarms were reported from north-western Nigeria. Unfortunately the observers failed to produce specimens for identification purposes. As it is now known that swarms of the Desert Locust, *Schistocerca gregaria*, Forsk., and of the Tree Locust, *Anacridium moestum*, Serv., may occur in the part of Nigeria from which the swarms were reported, their identity must remain obscure. In June 1929, a European saw swarms near Lake Chad which subsequently bred in that area. Again there is no evidence as to the species involved, and the report itself would have passed unnoticed had not the writer of this paper happened to "discover" it in a Provincial file in January 1930. Lean⁸ has assumed that these Chad swarms were probably *Locusta*, as he includes them and their progeny in Periods III and IV. It is just as probable that the Red Locust, *Nomadacris septemfasciata*, Serv., was the species forming the swarms, for *Nomadacris* hopper bands have been seen in the same area at the same time (August) every year from 1930 to 1933.

In October and November 1931, the writer made a preliminary survey of the shores of British Chad, in the course of which he found that phases *solitaria* and *transiens* of the Migratory Locust were present in most localities.

In recent years the shores of Lake Chad have been regarded with suspicion as being a possible reservation of the Migratory and Red Locusts. *Nomadacris* is not known to occur in any other part of West Africa; this fact and the presence of swarms during the last four years are the principal reasons for regarding Chad as a probable reservation of the Red Locust. The indications that Chad may be a reservation of the Migratory Locust are much less substantial and are, primarily, based upon the assumption that the swarms of June 1929 were those of *Locusta*.

One of the objects of the preliminary survey mentioned above was to select a suitable locality in which to carry out ecological investigations on the two species of locusts. The writer decided that Kalkala, a Shuwa Arab hamlet at the south-western corner of the Lake, was the best area for the work, and a field laboratory was erected

there in June 1932. A study of the ecology of *Locusta* and *Nomadacris* and other ACRIDIDAE was made between 21st December 1932 and 30th June 1933. The results of this study and of the preliminary survey form the subject matter of the present paper.

Mr. A. M. Gwynn arrived at Kalkala in early September 1933, in order to continue the ecological research begun by the writer.

2. Preliminary Survey of Chad Area in 1931.

Examinations of the Lake shore were made at the nine points shown on the map (fig. 1) between 10th October and 10th November 1931. The temporary absence of

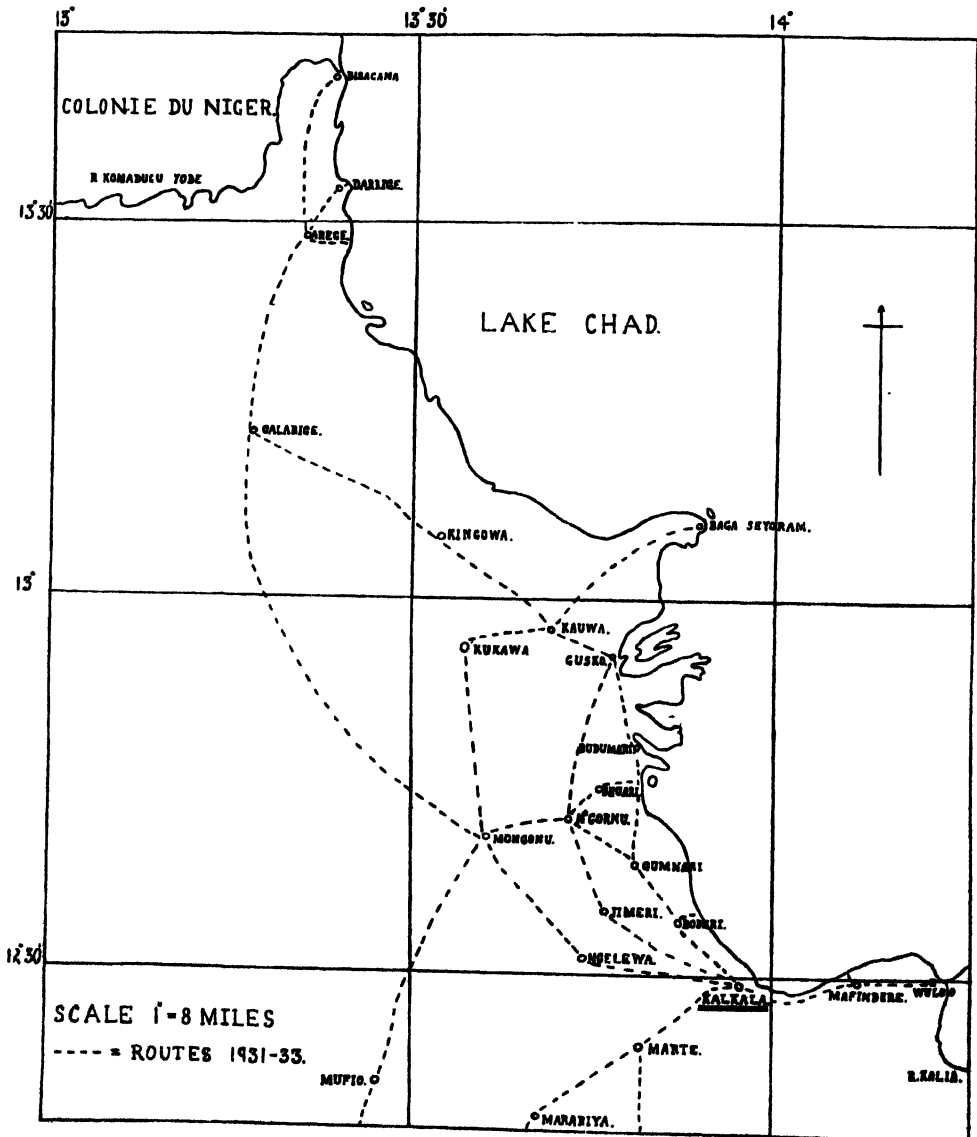


Fig. 1.

inhabited villages within reach of the shore between Baga Seyoram and Arege made it impossible to visit the Lake between those points. Many of the villages in northern Chad are only occupied temporarily and it is almost impossible to obtain reliable information as to whether the next village, usually some 17 miles away, is inhabited or not. The difficulty of travelling in this area is increased by the absence of any adequate map. The shore from Kalkala eastwards to French Cameroon is subject to extensive inundation and could not be examined at the time the survey was made. It was only possible to examine the true shore of Chad in the four most northerly localities, *i.e.*, Bisagana to Baga Seyoram. In each place there was open water fringed by a belt of *Cyperus papyrus*, Linn., from 5 to 40 yards in width; no Orthoptera were found in the papyrus or in various reeds adjoining the belt. Belts of *Echinochloa pyramidalis*, H. & C., were present at Bisagana, Darrige and Arege; many migratory Locusts were found in this grass at Bisagana, but there were none at all at either of the other two localities. Most of the locusts were phase *solitaria* or *transiens* adults and a few solitary hoppers were found.

In the more southerly localities the lake had flooded the country to a distance of about two miles from the true shore. A few Migratory and Red Locusts were found at Gusko and Kalkala; both species occurred in greater numbers at Shuari, but neither was abundant.

Officers who had taken part in the Chad anti-locust campaigns of 1930 and 1931 informed the writer that hoppers had been numerous at Bisagana and to the south of a line from Baga Seyoram to Kukawa (fig. 1) in each year. In the intermediate area a burr-bearing grass, *Cenchrus catharticus*, Del., is very abundant, and it is possible that the presence of this grass deters locust swarms from ovipositing in that region. While at Mongonu in September the writer witnessed the passage of a large band of *Locusta* hoppers through a patch of *C. catharticus* about 400 yards in width. The fallen burrs entangled a number of hoppers, and many were impaled by burrs still attached to the grass; the impalement of hoppers usually occurred during the periods of ecdysis.

As a result of this brief preliminary survey it was very tentatively concluded that only a relatively small area, comprising about one-half or less of the shores of British Chad may offer conditions suitable for the production of the swarming phase of *Locusta* from the solitary phase.

3. Conditions round Kalkala in 1933.

Kalkala is situated near the south-western corner of Lake Chad. Its approximate geographical position is Lat. 12° 30' N., Long. 13° 58' E., and its height above sea-level is about 900 feet. Most of the ecological work was carried out within a radius of two miles of the village. The southern limit of the survey area was about four miles from Lake Chad (fig. 3).

The principal object of the investigation was to study the ecology and bionomics of the Migratory Locust, *Locusta migratoria migratorioides*, R. & F., and of the Red Locust, *Nomadacris septemfasciata*, Serv., in the hope of discovering whether the Chad area is a reservation of those species. If that were found to be the case, it was hoped that the research might throw some light on the nature of the factors which, periodically, induce the transition from phase *solitaria* to *gregaria*, and that it might suggest some means of preventing the transition from taking place in the future. It was, of course, realised that a comparatively brief study in one small area was not likely to solve the problem and that probably research over a number of years will be necessary. Further, the final proof that an area is a reservation must be through the observer actually witnessing the transition from the solitary to the gregarious phase. As *Locusta* had been swarming for about four and a half years

before the beginning of the work it was improbable that, even if Chad were a reservation, the transition would still be in progress. The position with regard to *Nomadacris* was entirely different. Mr. P. G. Butcher found clusters of hoppers near Chad on 21st July 1930, which were subsequently proved to be those of the Red Locust. In August and September of 1930 and of the succeeding two years hoppers of this species were abundant in the lacustrine area; but they formed rather loose bands and, so far as is known, none was of the typical *gregaria* coloration. After the conclusion of the hopper campaign each year a few swarms of adult *Nomadacris* were observed; they were generally not dense, and were variable in their direction of flight. With one exception, no swarm was reported from localities more than about 12 miles from the Lake. An interesting fact was the presence of a copulating swarm of *Nomadacris* at Auno (about 80 miles south-west of Kalkala) on 17th July 1930; the observer forwarded specimens. This is the first definite record of the Red Locust in Nigeria.

Observations were made also on the ecology of all other species of ACRIDIDAE in the survey area. It has been found convenient first to describe the ecological work at Kalkala as a whole and later to devote special sections of the paper to the Red and Migratory Locusts.

As this paper is the first account to be written of ecological research in the vicinity of Lake Chad it has been found necessary to describe the habitats frequented by Orthoptera in some detail.

Agriculture.

The principal occupation of the people is farming; fishing is only practised at certain seasons of the year. One herd of cattle and a number of goats were kept at Kalkala by a small colony of herdsmen throughout the six months. In early April a large colony of nomadic Arabs arrived with their herds and constructed a temporary village about two hundred yards to the east of Kalkala. These nomads left the area in the first half of June, when their herds had grazed down most of the marsh grass vegetation within easy reach of Kalkala. After the beginning of the rains in May several species of grass sprang up in the inland "fadamas" and it was no longer necessary for the Arab herdsmen to keep close to the shore of Chad.

The chief crops grown by the Arabs are a dry-season guinea-corn known as "mazakwa" (*Sorghum cernuum*, Host.), a bulrush millet (*Pennisetum spicatum*, Koern.), maize, and cowpeas (*Vigna catjang*, Walp.). Less important crops are tobacco, wheat, cotton, groundnuts (*Arachis hypogaea*, Linn.), okra (*Hibiscus esculentus*, Linn.), and a number of Cucurbitaceous plants.

As described below, Lake Chad overflows its banks in September and floods much of the country within three or four miles of its low-water shore. When the writer arrived at Kalkala on 21st December 1932, the floods had already started to recede. The "mazakwa" fields were in heavy soil at the edge of the inundated area; the crop was harvested between 22nd December and the middle of January. Cowpeas were planted from mid-December to mid-March as the flooded area became available for sowing. The central parts of the flooded areas were often sown with Cucurbits and tobacco. The harvesting of cowpeas began at the end of March and was not completed until mid-June; after most of the pods had been gathered the Arabs removed much of the haulm to the village, where it was fed to their horses. Maize is planted on the old bean-land in July.

P. spicatum sowing was begun after the first rains in mid-May on land near the village. The soil contained about 20 per cent. silt and clay and had not been flooded by the Lake; a soil sample taken at the edge of the bean-land contained nearly twice as much silt and clay.

Cotton was sown in patches on sandy soil. Wheat was sown in December at the edge of a pond and was irrigated by means of shadoofs; the harvest took place between mid-March and mid-April.

Sketch-maps (figs. 2, 3) show the principal areas under "mazakwa," cotton, cowpeas and bulrush millet. No ACRIDIDAE were observed in the "mazakwa" fields; but cotton proved to be an important habitat of several of the larger species, including the Tree Locust, *Anacridium moestum*, Serv. Several geophilous species frequented the cowpea and millet fields.

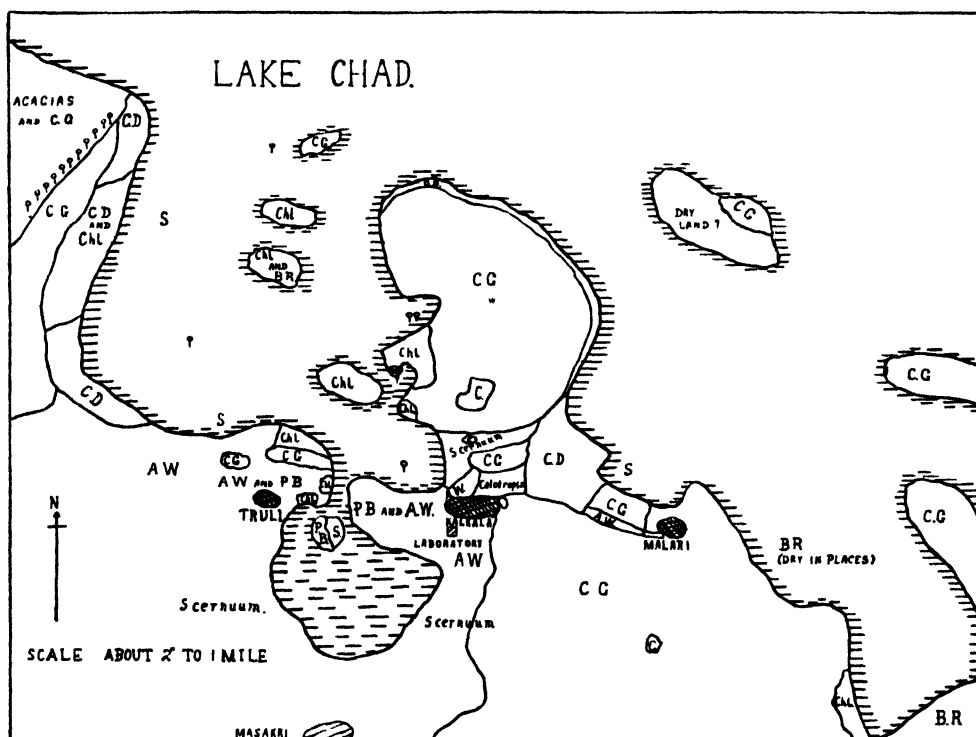


Fig. 2. Sketch map of survey area at high water 31.xii.32.

C.G., *Cymbopogon giganteus*, Chiov.; C.D., *Cynodon dactylon*, Pers.; Chl., *Chloris gayana*, Kunth.; B.R., *Brachiaria ramosa*, Stapf; E.P., *Echinochloa pyramidalis*, H. & C.; P.B., *Peristrophe bicalyculata*, Nees.; A.W., weeds on old farmland, principally *Pulicaria undulata*, DC.; L.G., *Vossia cuspidata*, Griff.; S, *Sorghum* sp. aff. *aethiopicum*, Rupr.; C, cotton.

As might be expected man proved to be a biotic factor of primary importance. It will be seen that there were three villages in the central part of the survey area. Although the cultural operations of the inhabitants of these villages naturally had a profound effect upon the vegetation in their immediate neighbourhood, the grazing of the nomads' herds was of greater importance from an ecological point of view. Before the nomads arrived at Kalkala in April vast herds were driven daily from villages to the south-east to the grassland east of Malari. Early in the survey period the writer was under the impression that, as the Lake receded, enormous areas of marsh grass would become available for Orthoptera. The effect of the cattle feeding on and tramping down the grass was so considerable that there were very few areas of marsh grass left undisturbed and providing suitable conditions for grasshoppers. In the course of treks northwards to Gusko and eastwards to Wulgo (fig. 1) it was seen

that conditions in the vegetational belts fringing Chad were very similar to those at Kalkala and that there were few areas which had not been visited by cattle.

Lake Chad.

Abadie¹ has stated that the total area of the Lake is about 25,000 square kilometres, of which about 5,000 are occupied by islands and the remainder by water and reeds. Boyd Alexander's exploration of Chad,² between December 1904 and May 1905, showed that there were few patches of open water at that time of the year. From a map in his book describing the exploration it appears that the south-western part of the Lake is really a vast marsh. It is extremely difficult to obtain reliable information about Chad from the Arabs, as they do not possess canoes and have a marked aversion to wading through the reeds on account of hippopotami—one of

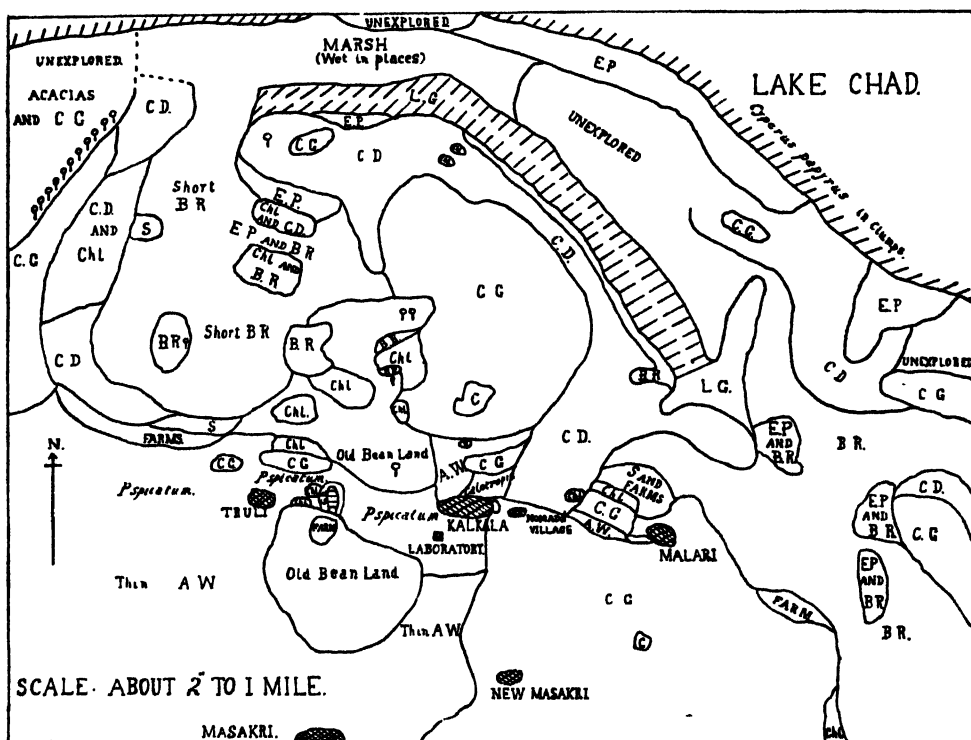


Fig. 3. Sketch map of survey area at low water 30.vi.33. (For explanation of lettering see figure 2.)

which animals killed a cow near Kalkala in March. The writer arranged that some Buduma people living some miles to the north should construct a papyrus canoe for him. The Buduma arrived with the canoe from Baga Ngelewa on 7th March and said that they had had to work their way through dense reeds for the whole distance; they also said that the journey of about eight miles had taken them four days to accomplish. This was possibly an exaggeration, but it seems safe to assume that they encountered practically no open water on the way. The canoe required twenty men to carry it over dry land and was not suitable for exploration work on account of its lack of durability.

The principal influents are the Komadugu Yobe in the north-west and the Chari and Kalla rivers in the south. As the result of the ingress of flood waters, principally from the Chari, the Lake overflows its banks in the autumn and inundates large areas to the south and south-west. There is considerable annual variation in the extent

of the inundations. This is the result of differences in the amount of water carried by the influents each year and, to a lesser extent, of annual fluctuations in the strength and duration of the north-easterly "harmattan" wind. The vast plain of Bornu to the west of Chad is, with the exception of the series of dunes mentioned by Migeod,⁹ practically devoid of elevations with a height of more than about six feet above the plain.

The question of the variation in the degree of flooding each year is obviously of great importance. It is conceivable that either unusually high or low floods could cause the solitary phase individuals of a locust species to be crowded together, with the result that the gregarious instinct would develop in the next generation and finally, swarms would be produced. Unfortunately, records of the annual changes in the level of the Lake have not been kept by the British. The writer has heard that the French have made hydrographical studies, but has not yet been able to obtain a copy of their data. It is a historical fact that the floods reached as far west as Kukawa about 1871. Migeod⁹ was informed by natives that the Lake reached N'gornu in August 1921.

TABLE I.
Kalkala Meteorological Records.

1933 Months	Wind direction. Days	Av. max. temp. in shade ° Fahr.	Av. min. temp. in shade ° Fahr.	Mean temp. in shade ° Fahr.	Greatest Diurnal variation ° Fahr.	Relative humidity		Rainfall in inches	No. of days on which rain fell
						9 a.m.	3 p.m.		
January	N.E. 18 N. 13	87.2	59.4	73.3	34.8	49%	38%	—	—
February	N.E. 16 N. 10 E. 1 S.W. 1	92.5	57.7	75.1	47.6	41%	34%	—	—
March	N.E. 21 N. 6 W. 3 N.W. 1	99.5	65.3	82.4	45.8	39%	34%	—	—
April	N.E. 10 N. 8 S.W. 6 E. 2 W. 2 S. 2	108.7	70.5	89.6	52.6	42%	38%	0.06	1
May	W. 11 S.W. 9 E. 7 N.E. 4	105.3	72.1	88.7	47.0	48%	40%	2.405	7
June	S.W. 17 W. 7 E. 4 S. 2	101.1	74.6	87.8	35.6	62%	46.5%	1.37	7

The writer was told by Buduma that the water was usually high once in five years; 1929 and 1932 were described as flood years and 1930 and 1931 as low water years. A Kalkala Arab stated that about 16 years ago the floods were exceptionally extensive, and in the following year they were so small that the pond between Kalkala and Truli dried up and wells had to be dug. It would be useless to attempt to correlate locust outbreaks in the past with small or great flood years, as the information

available is too meagre and inexact. The writer visited Kalkala for a few days in November 1931, and noticed that the floods were then about $\frac{1}{2}$ mile from the village in a north-westerly direction and about one mile to the north-east. The Lake was not then connected with the pond between Kalkala and Truli (figs. 2 and 3). In December 1932—some time after the floods had begun to subside—the inundations were about 50 yards to the north-west of Kalkala and about 900 yards to the north-east. It is evident that the Budumas' information concerning 1931 and 1932 was correct.

For the first four months of the survey there was a belt of deep water or marsh which prevented the true shore of Chad from being approached from Kalkala. In late April the writer waded through marsh to the north of Malari and reached the Lake to the north-east of that village. A strip of tall marsh-grass ran southwards from the true shore and joined the *Vossia cuspidata* belt shown on the map (fig. 3). At that time this strip and the *Vossia* belt were, not unnaturally, thought to represent the true shore of Chad. It was not until the last week of the survey that the marsh had dried up sufficiently to disclose the fact that there was a strip of dry land to the N.N.E. of Kalkala and that the *Vossia* belt was not the true shore of the Lake. For several months an unknown dry area existed within two miles of Kalkala. The water in the *Vossia* belt was always too deep to allow a man in thigh-waders to cross it. The tenacious nature of the mud and the hordes of day-feeding mosquitos made the survey of the lacustrine area as unpleasant as it was difficult to accomplish.

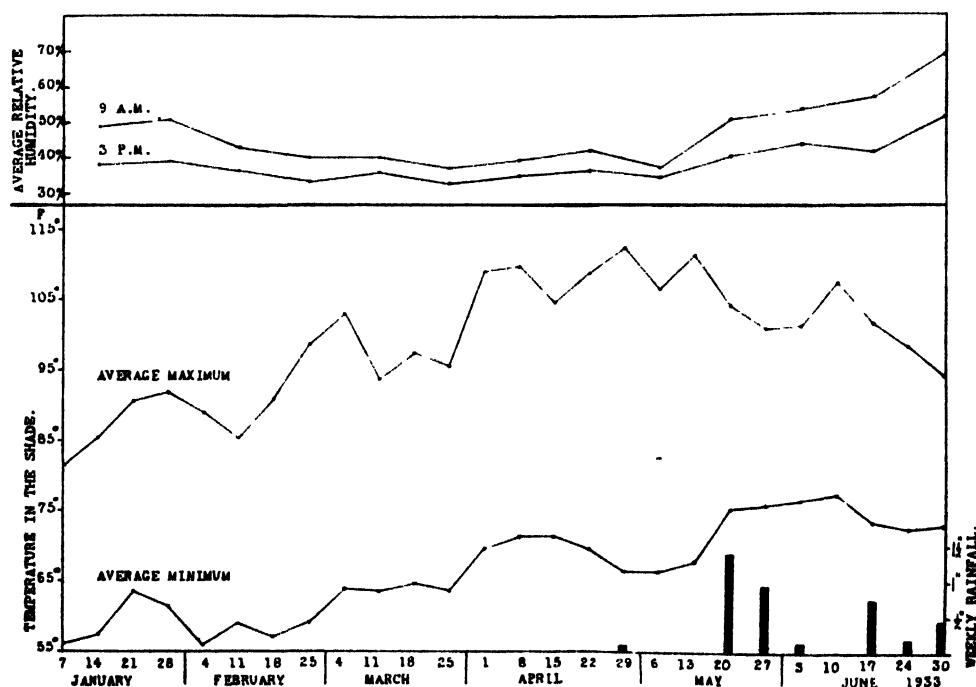


Fig. 4. Kalkala.

Climate.

Meteorological records were kept at Kalkala from 1st January to 30th June 1933. On 1st October 1931, the writer opened a meteorological station at Mongonu, a town about 26 miles W.N.W. of Kalkala, and about 13 miles west of Chad. The records were taken by a Kanuri school-teacher until the station was closed by the writer on 31st January 1933.

The Kalkala records are shown in Table I and graphically in fig. 4. It will be seen that the humidity was remarkably constant until after the beginning of the rains in mid-May. Up to mid-March there was often heavy dew in the early morning. The rise in the maximum and minimum shade temperatures in early April coincided with the cessation of the "harmattan."

Table II below shows that the rains in the Chad area lasted from May to October in 1932; the first heavy shower occurred on 17th May and the last rain fell on 7th October. In 1933 the rains began on 14th May (there was a fall of 0.06 inches on 29th April).

TABLE II.
Mongonu Meteorological Records.

Month and year	Direction of prevailing winds	Average max. temp. in shade ° Fahr.	Average min. temp. in shade ° Fahr.	Greatest diurnal variation ° Fahr.	Rainfall in inches	No. of days on which rain fell
1931						
Oct. ...	S W. & N.E.	103.5	71.4	41	0.30	1
Nov. ...	E. & N.E.	97.1	63.6	41	—	—
Dec. ...	"	93.0	58.0	44	—	—
1932						
Jan. ...	"	85.5	57.0	48	—	—
Feb. ...	"	94.0	57.0	42	—	—
Mar. ...	"	103.8	68.2	44	—	—
Apr. ...	"	109.1	73.0	45	—	—
May ...	W. & S.W.	109.4	76.4	44	0.73	2
June ...	"	107.6	77.7	33	{ Readings only from 1st to 3rd and from 18th to 30th. No rain.	—
July ...	"	96.1	73.9	31		9
Aug. ...	"	91.7	66.2	27	8.26	17
Sep. ...	"	96.0	72.9	35	2.83	7
Oct. ...	Variable	104.0	74.0	40	0.88	2
Nov. ...	E. & N.E.	97.6	61.8	45	—	—
Dec. ...	E. to N.	87.2	55.8	40	—	—
1933						
Jan. ...	"	90.1	61.4	36	—	—

Both the average maximum and average minimum shade temperatures for January 1933 were between two and three degrees lower at Kalkala than at Mongonu; the proximity of Chad was probably the cause.

The high maxima in October occur after the rains have ceased and at a time when the wind direction is veering from south-west to north-east. The last S.W. wind was recorded on 24th October in 1931 and on 4th November in 1932.

Meteorological records are taken at Maiduguri, about 70 miles S.W. of Kalkala. The total rainfall from April to the end of June was 9.55 inches at Maiduguri, as

compared with 3.835 inches at Kalkala. The mean shade temperature was from 2.5 to 4 degrees higher at Maiduguri than at Kalkala for the first four months; but the range in temperature was markedly greater at Kalkala, and higher absolute maxima were recorded in every month except January.

4. Habitats frequented by Acrididae.

The term habitat is here used in its wider sense to denote the combination of climatic, biotic and other factors influencing the Acridid population of a particular locus. The various habitats are designated by the generic names of the dominant plants occurring in them.

For convenience the vegetation and soils are described first, then the distribution of the ACRIDIDAE and, finally, the microclimatic and faunistic differences of the various habitats.

Vegetation and Soils.

The flora of the survey area was not rich in species; less than 70 species of uncultivated plants were recorded. Nearly all the trees belonged to the genera *Acacia* or *Zizyphus* and, except in the immediate neighbourhood of villages, there were only seven trees exceeding 15 feet in height. An *Acacia* "forest" formed the north-western boundary of the area.

TABLE III.
Soil Analyses.

	<i>Brach.</i> (Malari)	<i>Brach.</i>	<i>Cyn.</i>	<i>Chl.</i>	<i>Pcr.</i>	<i>Cymb.</i>	<i>Cymb.</i> (Profile)			
			(One	foot samples)			0-6"	6-10"	10-19"	19-24"
Coarse sand ...	59.9	49.7	68.1	58.7	70.5	73.8	70.7	47.7	65.2	59.3
Fine sand ...	20.1	13.3	27.2	16.2	8.9	16.6	17.6	10.0	30.3	31.9
Silt and clay ...	20.0	37.0	4.7	25.1	20.6	9.6	11.7	42.3	4.5	8.8
Chemical analysis of Fine Earth										
pH ...	6.6	7.1	9.2	8.2	6.5	6.3	6.0	5.5	6.0	5.5
Total Exch. Bases (mg. Eqs.) ...	6.69	8.99	2.94	7.32	5.81	3.18	3.82	5.58	0.95	1.91
Organic matter ...	0.95	1.24	0.24	0.73	0.70	0.35	—	—	—	—
Nitrogen ...	0.046	0.058	0.013	0.032	0.038	0.017	—	—	—	—

Sketch-maps (figs. 2 and 3) portray the survey area at the beginning and end of the period and indicate the vegetational belts which are subject to inundation. It should be mentioned that some of the "islands" shown in the map (fig. 2) may have actually been under water in December; the depth of the flood water and the absence of canoes precluded the determination of the extent of dry land in the middle of the inundated area.

Map (fig. 3) shows that the majority of the country is covered by various species of grasses and that the bulk of the farm-land is situated in the south-western part of the area. The reason for the incomplete exploration of the northern coastal belt has been given above.

As might be expected the old farm-land was comparatively rich in species; but the extensive grassland was less complex, as most of the grass habitats consisted almost entirely of one species. At the junctions of certain grass habitats there was no

admixture of species, but it was more usual for a transitional belt to be present in which both species were represented. During the six months there were considerable changes in the condition of the vegetation due, chiefly, to the recession of the Lake, climatic changes and the activities of man.

The soils were of three main types ; the first a clay (silt and clay content from 20 to 37 per cent.), the second a very alkaline sand, and the third an acid sand. Parts of the clay type and almost all of the alkaline sand are subject to inundation by the Chad floods. Stones are entirely absent. Soil analyses are shown in Table III.

The Cynodon Habitat.

Cynodon dactylon, Pers., known by many vernacular names, of which Bermuda Grass, Bahama Grass and Dub are perhaps the most familiar, exists in belts between the "marsh grass vegetation" of Chad¹⁰ and the acid sandy soils not subject to inundation. In December nearly the whole of the *Cynodon* belts were under water. During the 1931 survey it was noticed that these belts frequently formed the high-water-mark of the floods. From Table III it will be seen that *C. dactylon* was found on soil containing 95.3 per cent. of sand and with the unusually high pH value of 9.2.

In most of the *Cynodon* habitats Dub was the only species present and formed a very dense covering. Occasionally *Lippia nodiflora*, Rich., a small Verbenaceous plant, was present. The average height of the Dub was about 15 inches when ungrazed by cattle and goats ; but as a result of grazing, it was usually seldom more than six inches high. Towards the end of the period the grass became very sparse in those parts of the belts which had not been under water during the floods. In addition, much of the Dub bordering the unflooded acid sand was burnt by the Arabs in May and June.

The average number of *C. dactylon* plants per square metre was 240 ; the average weight of a square metre of grass (cut at a height of one inch above ground-level) was 723 grammes. The proportion of soil covered at the base of the plants was almost 100 per cent.

The Cymbopogon Habitat.

Cymbopogon giganteus, Chiov., is a perennial varying in height from five to eight and a half feet. This grass occupied the acid sandy soils not usually subject to inundation ; the writer was informed by an Arab that about 16 years ago the floods were exceptionally extensive and covered much of the peninsula to the north of Kalkala. The *Cymbopogon* areas are dunes with an elevation a few feet higher than that of the surrounding country. As shown in Table III the soil contained 90.4 per cent. sand and had a pH value of 6.3. In addition to the ordinary one foot sample a profile was taken to a depth of two feet, which showed that there is a six inch layer of sandy soil overlying a four-inch stratum of heavy clay (42.3 per cent. silt and clay). Below the clay there is sandy soil containing only from 4.5 to 8.8 per cent. silt and clay. The pH values of the four layers were 6.0 or less (see Table III). The chemists who kindly made the soil analyses for the writer state that "The profile . . . shows a very striking variation in texture with depth, which is not unusual in alluvial deposits." It is probable that the superficial layer of sand is wind-borne and augmented by deposits brought by the "harmattan" each year.

There is a wide transitional belt between the *Cymbopogon* and *Cynodon* habitats ; when fires occur in these belts both grasses are burnt down to the ground. Bush fires in *Cymbopogon* growing alone have but little effect on account of the distance between the plants ; usually only the dead flowering shoots are burnt. *C. giganteus* is a tufted grass bearing flower-shoots from 5 to 8½ feet high ; these shoots were almost dead in December and only a very small number of fresh shoots were produced during the period. For the first four months the tufts of green leaves at the bases of the plants were about 9 inches high, after the rains began the leaves grew rapidly and some

were $2\frac{1}{2}$ feet in height by the end of June. The tufts increased considerably in width and became almost contiguous in parts of the belts, while the tornadoes broke down most of the old flowering shoots. The character of the habitat changed markedly in the six months. The Arabs clear land in the middle of the belts and plant cotton and groundnuts; when these farms are abandoned *Cymbopogon* rapidly reoccupies the land. It was observed that there were two types of this grass. one grew to a height of about 8 feet and was dense, and the other was about 6 feet high and comparatively sparse. It is probable that the sparse areas represented farm-land abandoned two or three years before.

A few small *Acacia* trees, some patches of *Aristida* sp. and a Malvaceous plant and a considerable number of Dead Sea Apple plants (*Calotropis procera*, R. Br.) were found in the habitat. One or two patches of dead *Pennisetum mollissimum*, Hochst., were also recorded.

The number of plants of *Cymbopogon* per square metre was found to be : dense 60, sparse 15. The average weight of a square metre of dense grass was 1,191 grammes, while 60 per cent. of the soil at the base of the plants was covered. *C. giganteus* was but little grazed by cattle and goats.

The Chloris Habitat.

Chloris gayana, Kunth., or Rhodes Grass, is a perennial about 4 feet in height. It occurred in patches, sometimes as much as 20 acres in area, at the edge of the *Cymbopogon* belts or in the middle of the inundated area. A soil sample taken in *C. gayana* contained 25.1 per cent. silt and clay and had a pH value of 8.2. There was no transitional belt between this grass and *Cymbopogon*.

The writer was informed that two *Chloris* patches at the edge of the *Cymbopogon* peninsula were under cultivation about 16 years ago, and that the grass became established after the unusually heavy flood year mentioned above. Bews¹⁰ states that, in South Africa, species of various genera including *Chloris* are usually dominant for a time on ploughed grassveld afterwards allowed to remain "fallow" and on ordinary cultivated fields after harvest.

The patches at the edge of the peninsula consisted solely of *C. gayana*; but those in the inundated area were composed of *C. gayana* and either *C. dactylon* or *Brachiaria ramosa*, Stapf. Usually the centres of the islands were covered with Rhodes Grass alone and the margins with a mixture of that grass and one of the two species mentioned in the preceding sentence.

C. gayana is a tufted grass which bears numerous inflorescences; in the damper parts of the belts flowering continued throughout the period. In some parts of the habitat the tufts were contiguous and in others were about two feet apart. The average number of plants per square metre was 40, the average weight of a square metre of this grass was 879 grammes, and 48 per cent. of the soil at the base of the plants was covered.

Although Rhodes Grass is an excellent cattle food the Arabs' herds did not graze the *Chloris* belts during the period. Bush fires swept through most of the belts, but they had comparatively little effect on the grass until May.

The Brachiaria Habitat.

Brachiaria ramosa, Stapf, is a hydrophilous grass and was most abundant in the channel to the north-west of Kalkala (fig. 2) and in the marshy area to the east of Malari, which is probably part of the mouth of the river Yadseram. In January the only place where this grass was not under water was in the south-eastern corner of the survey area; by the end of May all of the *Brachiaria* habitat was free from water, though the soil was still very wet in the centres of the various marshes. In the drier parts of the habitat the grass was from $2\frac{1}{2}$ to $4\frac{1}{2}$ feet high and bore inflorescences in

January, in the central sections of the marshes *B. ramosa* was very short and was not frequented by ACRIDIDAE. The high grass was not mixed with other species, whereas short *Brachiaria* was sometimes associated with *Echinochloa pyramidalis*, H. & C., and a Convolvulaceous plant, which was probably *Ipomoea aquatica*, Forsk.

Two soil samples were taken, the first at the edge of the north-western channel and the second near Malari. Both samples were from "tall" *Brachiaria*. The north-western sample contained 37 per cent. silt and clay and had a pH value of 7.1, and the corresponding figures for the Malari soil were 20.0 and 6.6. It is of interest that the first of these samples was procured less than 50 yards from the sample taken in the *Chloris* habitat and yet contained nearly 12 per cent. more silt and clay. The *Brachiaria* formed a small belt between the *Chloris* and heavy swamp-land which was almost devoid of vegetation. *B. ramosa* also formed a narrow belt between *C. dactylon* and the "false shore"; in this area the grass was mixed with two species of *Cyperus* and was the grazing ground of several hippopotami early in the period. From December to February the largest area of tall *B. ramosa* (east of Malari) provided grazing for several thousand head of cattle, which were driven daily to the grass from the temporary villages of the nomadic Arab herdsmen. After the recession of the floods patches of tall *ramosa* were seen at the edges of the bean-land to the north-west. In this area the grass was about $4\frac{1}{2}$ feet high; there were 31 plants per square metre; the weight of one square metre was 2,169 grammes and 65 per cent. of the ground was covered at the base of the plants. At Malari the *ramosa* was $2\frac{1}{2}$ feet high and one square metre weighed 1,332 gms.

The Echinochloa Habitat.

Echinochloa pyramidalis, H. & C., or Limpopo Grass, is a perennial and grows about $7\frac{1}{2}$ feet in height. Patches of this grass occurred in the wettest parts of the Malari marsh where they were associated with short *B. ramosa* and *Ipomoea*. By the end of April the floods had receded sufficiently to allow an examination to be made of the lacustrine area to the north-east of Malari. There were between two and three hundred acres of *Echinochloa*; about one-fifth of the habitat was trampled down by cattle during May. The grass in this region was $5\frac{1}{2}$ feet high and varied in density; the part near the shore of Chad was much more densely covered than the remainder of the habitat. The weights of a square metre of dense and sparse *Echinochloa* were 5,613 and 2,325 gms. respectively. The dense grass covered 90 per cent. of the soil and the sparse 45 per cent. There were 154 plants to the square metre in the dense area and 64 in the sparse.

A soil sample was taken in the habitat to the east of Malari where tufts of tall *Echinochloa* ($7\frac{1}{2}$ feet) were growing in short *B. ramosa*. The top three inches were black in colour and contained 19.2 per cent silt and clay with a pH of 6.3, while the next nine inches were grey-brown with 23.8 per cent. silt and clay and a pH of 6.6. This soil was similar to that in which tall *B. ramosa* was growing at Malari. *Echinochloa* was much grazed by cattle.

The Sorghum Habitat.

Sorghum sp. aff. *aethiopicum*, Rupr., was about 12 feet in height and grew in the deeper parts of the floods; in February this grass marked the edges of most of the few remaining pools in the farm-land area. The plants had produced seeds by January and died when the water receded. By the end of the period young plants, about six feet in height, were present.

The Vossia Habitat.

The "false shore" was marked by a dense growth of a tall perennial grass, *Vossia cuspidata*, Griff. The examination of this habitat was impossible for the first four months on account of the depth of the water in which the grass was growing. From

April to May the herds fed chiefly on *Echinochloa* and *Vossia*, the cattle grazing down the grass to within a few inches of the water. All the grass on the inland side of the belt was eaten down for a distance of about 60 yards from its edge.

The Peristrophe Habitat.

Peristrophe bicalyculata, Nees. (Acanthaceae), is an erect annual about three feet in height. The sedge, *Cyperus bulbosus*, Vahl., and occasionally *C. dactylon* were sometimes present in the habitat; *C. bulbosus* was unimportant as there were only a few prostrate leaves on plants of this species. *P. bicalyculata* was found on old farmland and the high-water-mark of the floods could often be clearly seen by the condition of the plants in the belt. Those plants which had been inundated were dead, while others beyond the limit of the inundations were green and still bore a few flowers (December). By the end of January nearly all the plants were dead. The plants covered about 33 per cent. of the ground, there were 18 to the square metre and the weight of one square metre of dead vegetation was 765 gms. Parts of the habitat were cleared for bean-planting in January and further clearing took place in early May for the sowing of bulrush millet. The branches of the *P. bicalyculata* plants were interlaced at a height of about 18 inches above the ground; but owing to the absence of leaves, they did not provide much shade. A few young plants were noticed in the beanfields in March.

The soil in this habitat contained 20.6 per cent. silt and clay and had a pH value of 6.5. From Table III it will be seen that it was rather similar to the sample from the *Brachiaria* habitat at Malari.

The Pulicaria Habitat.

Between 30 and 40 species of plants were recorded from the old bulrush millet fields in late December. This land was not inundated. Patches of *P. bicalyculata* and scattered *Calotropis procera* plants were present in parts of the habitat. All the plants were flowering in late December. On 24th April an estimation was made of the amount of ground covered by these plants; four squares—each 100 square yards in area—were utilised for this investigation. It was found that about 185 out of the 400 square yards were covered. *Pulicaria undulata*, DC. (Compositae) formed 83 per cent. of the cover, while 5 other species accounted for the remaining 17 per cent. It will be seen that many of the species recorded in December had died down or were so rare that they did not appear in the sample areas. Most of the *P. undulata* plants were dead by mid-May when the land was cleared for millet-planting.

Other Habitats.

The bean and bulrush millet fields were frequented by geophilous species of ACRIDIDAE. One grasshopper species lived on *C. procera* or *Balanites aegyptiaca*, Del., which was extremely rare in the survey area. Many of the larger species frequented cotton fields. The burr-bearing grass, *Cenchrus catharticus*, Del., was not uncommon at the sides of the cattle-tracks passing through parts of the *Cymbopogon* belts, and harboured a number of species of grasshoppers. After the beginning of the rains, grasses, which were possibly *Aristida funiculata*, Trin. & Rupr., and *Schoenfeldia gracilis*, Kunth., sprang up and formed an important habitat of the recently hatched hoppers of several species of ACRIDIDAE.

5. Distribution of Acrididae.

Considerable difficulty was experienced in deciding upon the most satisfactory method of determining the abundance and ecological plasticity of the various species. Up to the end of February the ACRIDIDAE were not usually active before 8 a.m.; but in the succeeding months high temperatures caused the insects to become active about 1½ hours earlier. It was decided that it was essential to carry out the collecting

before the commencement of activity. A large number of species were present in the area and it was obviously impossible to obtain reliable data by any observational method. The method employed was as follows: Ten Arabs in line collected for 15 minutes in each habitat. The Arabs proved to be excellent collectors and were easily trained to keep their places in the line and to walk sufficiently slowly to ensure that the majority of the Acridid population of each collecting area was captured. After the end of March the collecting period was reduced to 7½ minutes, as the grasshoppers were active at 6.30 a.m. and the time available for the work was reduced to about 1 to 1½ hours each morning. Lack of funds made it impossible to collect more than two or three times in each habitat every month. As only two trained assistants were available, it was impracticable to estimate the Orthopterous population by means of numerous collections from small sample areas in each habitat.

Species of ACRIDIDAE in the Survey Area.

Specimens of all the unidentified species encountered were sent to Mr. Uvarov, of the Imperial Institute of Entomology, for determination. Many species proved to be either new to science or little known. As the new species have not yet been described it is necessary to utilise generic names in many cases. In several instances it was not possible to obtain a long enough series of specimens to enable specific identifications to be made. It is proposed to write an addendum to the present paper at a later date, when the new species have been named and the identity of the remaining species has been established.

Between 60 and 70 species of ACRIDIDAE were encountered; the specific identity of 35 of these is known. Many species were rare and others were only collected in the first month of the period.

Distribution in the principal Habitats.

Monthly collections were made in *Brachiaria*, *Cynodon*, *Chloris*, *Cymbopogon*, and *Peristrophe* throughout the period. There were few ACRIDIDAE in the *Pulicaria* habitat in January and early February; standardised collecting was begun in this locus in early March. It was not possible to collect in *Echinochloa* after January, as all the accessible grass was grazed down by cattle; the belts near Chad became accessible in late April, but were too far from Kalkala to enable the collectors to reach them before the Orthoptera became active.

Before tabulating the collecting results it is advisable to explain that the experimental work described in this paper differs essentially from much of the previous work on the ecology of Orthoptera. Gause⁶ carried out his investigations over a period of four weeks, C. Diver & P. Diver⁴ made their study in the course of two weeks. Their results necessarily are concerned with the relationship of the Orthopterous population to various habitats at a particular time. In the present study (over a period of six months) certain species disappeared after the first month and reappeared some months later, nymphs of other species were present at different times and, finally, the character of the habitats changed considerably during the period. It will be realised that the time factor is of great importance in the study of animal ecology. Certain writers,^{8, 11} quoted by Gause, have shown that the principal factor that influences the choice of one station or another by the Orthoptera is the microclimate. It is obvious that over a period of six months the microclimatic conditions in the various loci vary considerably, and that consequently it might be expected that different species of ACRIDIDAE would occupy stations which had previously offered unsuitable conditions. Conversely, other species would vacate stations which had become unsuitable. For this reason no attempt has been made in the present paper to express the average conditions required by each species and their ecological plasticity biometrically. In Gause's paper the degree of ecological plasticity of the various species is based upon their distribution in various habitats during the four weeks of research; presumably there would be only slight

changes in the microclimates of the habitats in so short a period. If the ecological plasticity of certain species were determined monthly by Gause's method considerable divergence would be found, as the choice of habitat is not usually dependent upon the vegetation *per se*, but upon a combination of factors of which the microclimate is the most important.

Table IV shows the average catch of ACRIDIDAE (taken in 15 minutes) each month in the six principal habitats. The abundance of each species is expressed as a percentage of the catch; when a particular species was present but represented less than 1 per cent. of the catch, an "x" is utilised. The specific names of *Locusta migratoria migratorioides*, *Acanthacris ruficornis citrina* and *Ornithacris cyanea terehicolis* are denoted by their initial letters. Separate data are not available for two species of *Chrotogonus* and three of *Euprepocnemis*. Swarms of *L. m. migratorioides* appeared in the area in the last two days of May and in early June. It was decided to omit phase *gregaria* of this species from the collecting results, as the swarms were generally distributed and were comprised of individuals which had not been present in the first five months of the survey. The figures shown for this species refer solely to the resident phases, *viz.*: *solitaria* and *transiens*. The figures for many of the species include hoppers.

It will be seen from Table IV that the composition of the grasshopper communities in the various habitats changed considerably during the period and that the two wettest stations, *viz.*: *Brachiaria* and *Cynodon*, had the smallest populations.

Table V shows (for the 22 most abundant species) the proportion of each occurring in each of the principal habitats in the half year. The index of abundance for each species is the sum of the average monthly catches in the various loci during the six months. It will be remembered that no collections were made in *Pulicaria* in January and February, therefore the index is the sum of 34 average catches.

Most of the ACRIDINAE showed a small degree of ecological plasticity, and many species were found only in the three wettest stations, *viz.*: *Brachiaria*, *Cynodon* and *Chloris*. *Pnorisa squalus*, St., was the only species in the subfamily which was abundant in one of the dry habitats; it is curious that this species superficially resembles certain of the CATANTOPINAE.

The OEDIPODINAE consisted of geophilous species, which were most abundant on bare ground in the farms. *Locusta* was an exception to this rule and occurred most frequently in the three wettest grass habitats.

The PYRGOMORPHINAE were found principally in the two non-gramineous loci. *Poeciloceris hieroglyphicus*, Klug, was almost always found on *Calotropis procera*, R. Br. (Asclepiadeae).

Among the CATANTOPINAE the two smallest species, *Acorypha howyi* and *Catantops haemorrhoidalis* were relatively the most abundant species in the non-gramineous habitats; while the two largest species, *N. septemfasciata* and *O. c. terehicolis*, gave the highest proportions in the tall grass habitat, *Cymbopogon*. The three species which were abundant in *Chloris*, *viz.*: *Ischnacrida* sp., *M. laticornis* and *Tristria* sp., are stick-like in shape and, when at rest, have the hind legs pressed against the abdomen. They are usually straw-coloured and as a result of their protective shape and coloration closely resemble the dead flower-shoots of *C. gayana*. *Mesopsis abbreviatus* is brown in colour and was found only in the *Cynodon* habitat. The remaining four species, *C. saucius*, *Caloptenopsis* sp. (1), *T. littoralis* and *Tylotropidius* sp., were found most often in the three driest habitats. As a whole the CATANTOPINAE exhibited a greater degree of ecological plasticity than any of the other subfamilies.

Later in the paper the data concerning every species encountered are discussed more fully and, in the majority of cases, an attempt has been made to deduce the

TABLE IV.

[illegible]

$x =$ less than 1%.

nature of the annual life-cycle from observations made in 1931 and 1933. These observations include the occurrence of nymphs and adults of each species, in all habitats, and their distribution in the Chad area.

TABLE V.

	Index of Abundance	Percentages occurring in					
		<i>Brach.</i>	<i>Cyn.</i>	<i>Chl.</i>	<i>Cymb.</i>	<i>Per.</i>	<i>Pul.</i>
ACRIDINAE							
1. <i>Acrida</i> sp.	134	47	37	4	1	7	4
2. <i>Amphicremna scalata</i> ...	35	85	6	9			
3. <i>Calephorus</i> sp.	53	1	97	2			
4. <i>Paracinema tricolor</i> ...	21	99	1				
5. <i>Platypterna</i> sp.	56	x	94	2			4
6. <i>Pnorisa squalus</i>	25	8	38	15	2	37	
OEDIPODINAE							
7. <i>Acrotylus blondeli</i> ...	13	10		4		63	23
8. <i>Locusta m. migratorioides</i>	18	38	30	20	1	11	
PYRGOMORPHINAE							
9. <i>Chrotogonus</i> spp. ...	36	2	11			56	31
10. <i>Pyrgomorpha cognata</i> ...	108	2	5			29	64
11. <i>P. kraussi</i>	40	1	3		1	60	35
CATANTOPINAE							
12. <i>Acorypha houi</i>	22				2	67	31
13. <i>Caloptenopsis</i> sp. (1) ...	49	1	6	8	15	49	21
14. <i>Catantops haemorrhoidalis</i>	12	4				32	64
15. <i>Catantops saucius</i> ...	168	2		6	41	28	23
16. <i>Ischnacrida</i> sp.	102	x	x	67	11	21	
17. <i>Nomadacris septemfasciata</i>	517	10	x	18	70	x	x
18. <i>Mesopsis laticornis</i> ...	44	3	23	46	15	11	2
19. <i>Ornithacris cyanea tereti-</i> <i>collis</i>	369	2	x	6	72	17	3
20. <i>Thisoecetrus littoralis</i> , subsp.	54				24	15	61
21. <i>Tristria</i> sp.	25	5	12	69	6	4	4
22. <i>Tylotropidius</i> sp. ...	134	x	x	11	31	47	10

x = less than 1%.

x = less than 1%.

Frequency of the Species.

The frequency of the various species of ACRIDIDAE in the main habitats is expressed below by Raunkiaer's method. For each habitat the total number of collections in the six months was utilised. If a particular species of grasshopper

occurred in 10 out of 20 catches its frequency would be 50 per cent. and it would be shown in the 41-60 group.

In a study lasting six months it would be preferable to work out the frequency for each month, for a species with an embryonic diapause would decrease in numbers after oviposition had occurred and would finally disappear. If the frequency of such a species were determined when the adults were dying, it is obvious that, owing to their greater rarity, the proportion of appearances in the sample collections would be lower than in the preceding month. In the present study the number of sample collections made each month was necessarily small, so it has been thought advisable to determine frequency over the whole period. For this reason figures are only given for those species which were known to be present (in the adult or nymphal stage) in the survey area throughout the half-year. Species with a frequency of less than 8 per cent. are not included.

Brachiaria.

- 81-100. *Acrida* sp.
- 41-60. *A. scalata*; *P. tricolor*; *N. septemfasciata*; *O. c. tereticollis*.
- 21-40. *Aiolopus* sp. (1); *L. m. migratorioides*; *C. saucius*.
- 8-20. *Calephorus* sp.; *P. squalus*; *A. blondeli*; *P. cognata*; *C. styliifer*; *Euprepocnemis* spp.; *Tristria* sp., *Tylotropidius* sp.; *T. speciosus*.

Cynodon.

- 81-100. *Acrida* sp.; *Calephorus* sp.; *Platypterna* sp.
- 41-60. *P. squalus*; *M. abbreviatus*; *L. m. migratorioides*.
- 21-40. *Aiolopus* sp. (1); *Chrologonus* spp.; *P. cognata*; *Tristria* sp.; *Caloptenopsis* sp. (1); *M. laticornis*; *N. septemfasciata*.
- 8-20. *A. scalata*; *Trilophidia* sp.; *P. kraussi*; *O. c. tereticollis*.

Chloris.

- 81-100. *Ischnacrida* sp.; *M. laticornis*.
- 61-80. *Tristria* sp.; *N. septemfasciata*.
- 41-60. *Acrida* sp.; *P. squalus*; *C. saucius*; *L. m. migratorioides*; *O. c. tereticollis*; *Tylotropidius* sp.
- 21-40. *C. styliifer*; *Caloptenopsis* sp. (1).
- 8-20. *A. scalata*; *Calephorus* sp.; *A. blondeli*; *Platypterna* sp.; *Euprepocnemis* spp.

Cymbopogon.

- 81-100. *N. septemfasciata*; *O. c. tereticollis*.
- 61-80. *C. saucius*; *Tylotropidius* sp.
- 41-60. *Caloptenopsis* sp. (1); *Ischnacrida* sp.
- 21-40. *M. laticornis*.
- 8-20. *Acrida* sp.; *P. squalus*; *A. blondeli*; *P. cognata*; *P. kraussi*; *A. houyi*; *A. r. citrina*; *C. styliifer*; *Tristria* sp.; *T. speciosus*.

Peristrophe.

- 81-100. *Tylotropidius* sp.; *O. c. tereticollis*.
- 61-80. *Ischnacrida* sp.; *C. saucius*; *Caloptenopsis* sp. (1); *P. kraussi*.
- 41-60. *P. cognata*; *Chrologonus* spp.
- 21-40. *Acrida* sp.; *A. blondeli*; *N. septemfasciata*; *A. houyi*; *M. laticornis*; *P. squalus*.
- 1-20. *Trilophidia* sp.; *C. styliifer*; *Tristria* sp.; *A. r. citrina*; *Euprepocnemis* spp.

Pulicaria.

- 81-100. *P. cognata*; *Tylotropidius* sp.
 61-80. *P. kraussi*; *C. saucius*; *Caloptenopsis* sp. (1).
 41-60. *A. blondeli*; *Chrotogonus* spp.; *Tristria* sp.; *Platypterna* sp.
 21-40. *Acrida* sp.; *P. squalus*; *O. c. tereticollis*; *A. houi*.
 1-20. *L. m. migratorioides*; *Trilophidia* sp.; *A. r. citrina*; *N. septemfasciata*; *C. styliifer*; *M. laticornis*; *T. speciosus*.

It will be seen that the distribution of species over the two non-gramineous habitats was very similar. The chief differences were the complete absence of *Ischnacrida* sp. from *Pulicaria* and of *Platypterna* sp. from *Peristrophe*, and the comparative rarity of *O. c. tereticollis* in collections from the *Pulicaria* habitat. The humidity of *Pulicaria* was undoubtedly higher than that of *Peristrophe*, for the green plants in that habitat gave a much denser cover than the dead plants of *P. bicalyculata*. The difference in humidity would account for the absence of *Platypterna* sp. from *Peristrophe* and of *Ischnacrida* sp. from *Pulicaria*. It should be mentioned that the distribution of certain species with a prolonged imaginal diapause altered greatly some weeks before the commencement of breeding; *C. saucius* and *O. c. tereticollis* abandoned the grassy habitats and spread to the farmland and *Pulicaria* areas. During the last six weeks of the survey large numbers of *N. septemfasciata* adults entered the collecting region from the coastal strip to the north; in June this species was common in habitats where it had seldom, if ever, been seen before.

Population of mixed Habitats.

Examination of the *Cymbopogon-Cynodon* areas showed that the ordinary *Cymbopogon* community was present in approximately the same proportions; but the species characteristic of *Cynodon*, viz.: *Calephorus*, *Platypterna*, *Acrida* and *Mesopsis abbreviatus*, were entirely absent.

A comparison of the populations of *Chloris* and *Chloris-Brachiaria* showed that *Acrida* and *A. scalata* were more abundant in the mixed habitat than in *Chloris*; but *O. c. tereticollis*, *C. saucius* and *Ischnacrida* were far less numerous, while *Tylotropidius* was entirely absent from *Chloris-Brachiaria*. There was little difference in the numbers of *M. laticornis* and *Tristria* in the two habitats. The mixed habitat was more humid than the *Chloris*; it bore a denser covering of grass and was partly flooded early in the period. The distribution of the species mentioned above proved conclusively that the ACRIDIDAE are influenced by the microclimate rather than by the actual vegetation in their choice of stations.

Effects of Desiccation upon the Acridid Community.

Standard collections were made each month in *Brachiaria* at Malari, which became progressively more dry (from January to April) as the season advanced. This was due to climatic changes and the recession of the lake. The total catches in each of the four months were 47, 22, 21 and 36 respectively. The number of individuals belonging to xerophilous species of the subfamily CATANTOPINAE included in these totals were 2, 2, 6 and 14; these figures indicate that the change in the microclimate was followed by an ingress of species which are rare in, or absent from, humid habitats.

Comparative collections were made in dry *Brachiaria* and in wet *Brachiaria* at Malari on the following dates: 6th Feb., 9th May and 14th June. In each case there was a distance of less than half a mile between the dry and wet areas. The sum of the catches in each type of habitat is shown in Table VI.

It will be seen that 12 species were represented in dry *Brachiaria* and only 6 in wet, although the total catch in the latter habitat was more than $2\frac{1}{2}$ times as great ; only two species were common to both habitats.

Many other examples could be given of changes in the composition of the Acridid population as a result of the gradual desiccation of various habitats. It is obvious that, were it practicable, it would be preferable to divide the area into microclimatic rather than vegetational zones and to study the distribution of ACRIDIDAE in the climatic sub-areas. Every month it would be necessary to readjust the limits of the various microclimatic zones. Such a procedure would elucidate the changes responsible for the local migration of the various species of ACRIDIDAE. It should be explained that in the standard collections in habitats where the microclimate was changing, population samples were taken from both dry and wet areas and the mean was utilised as the monthly index of distribution. In the *Cynodon* habitat the grasshoppers moved towards the lake as the water receded, so, each month, collecting was carried out in the wetter section of the locus.

TABLE VI.
Showing the populations of dry and wet *Brachiaria*.

	Dry <i>Brachiaria</i>	Wet <i>Brachiaria</i>
<i>Acrida</i> sp.	19	74
<i>Aiolopus</i> sp. (1)	1	6
<i>A. scalata</i>	2	—
<i>P. tricolor</i>	—	46
<i>P. squalus</i>	8	—
<i>Platypterna</i> sp.	1	—
<i>L. m. migratorioides</i>	3	—
<i>Calephorus</i> sp.	1	—
<i>P. cognata</i>	6	—
<i>C. saucius</i>	2	—
<i>C. stylifer</i>	—	1
<i>M. laticornis</i>	—	2
<i>O. c. tereticollis</i>	3	—
<i>N. septemfasciata</i>	—	1
<i>Tylotropidius</i> sp.	1	—
<i>T. speciosus</i>	4	—
Total catch	51	130

6. Microclimatic Observations.

The only instruments available for recording air temperatures in the open were six thermometers graduated from 15 to 152°F. The writer has been informed by an expert meteorologist that the reading of an unshielded thermometer is affected not only by the amount of radiation that falls on the bulb and by the air temperature, but also by the strength of the wind. For this reason the actual readings are not recorded below. Three thermometers were attached, at different levels, to each of two posts, which were set up facing due east in different habitats. Readings were taken hourly from 6.30 to 11.30 a.m. by two observers. This operation was repeated in various pairs of habitats on different days.

Very few humidity records were taken, as the only available whirling hygrometer was broken by an assistant early in the period. The ordinary type of wet and dry bulb instrument was not suitable for field work.

Temperature.

Comparative readings were taken at ground-level, 1 ft. and 2 ft. in *Cymbopogon*, *Chloris*, *Peristrophe* and *Brachiaria*; records were also made of the temperatures at ground-level and 1 ft. in *Cynodon* and each of the above habitats.

As might be expected, the lowest temperatures were recorded in the wettest habitat, viz.: *Brachiaria*. The differences in temperature, at ground-level and at 1 ft., between *Brachiaria* and the other four habitats are shown in fig. 5. All the readings were taken in the second half of March. It will be seen that *Brachiaria* was colder than any other habitat at ground-level from 6.30 to 11.30 a.m.; but, at 1 ft., was usually hotter than *Cynodon* and *Peristrophe* after 8.30 a.m. It was found that there was little difference in temperature between any pair of habitats at a height of 2 ft. above ground-level.

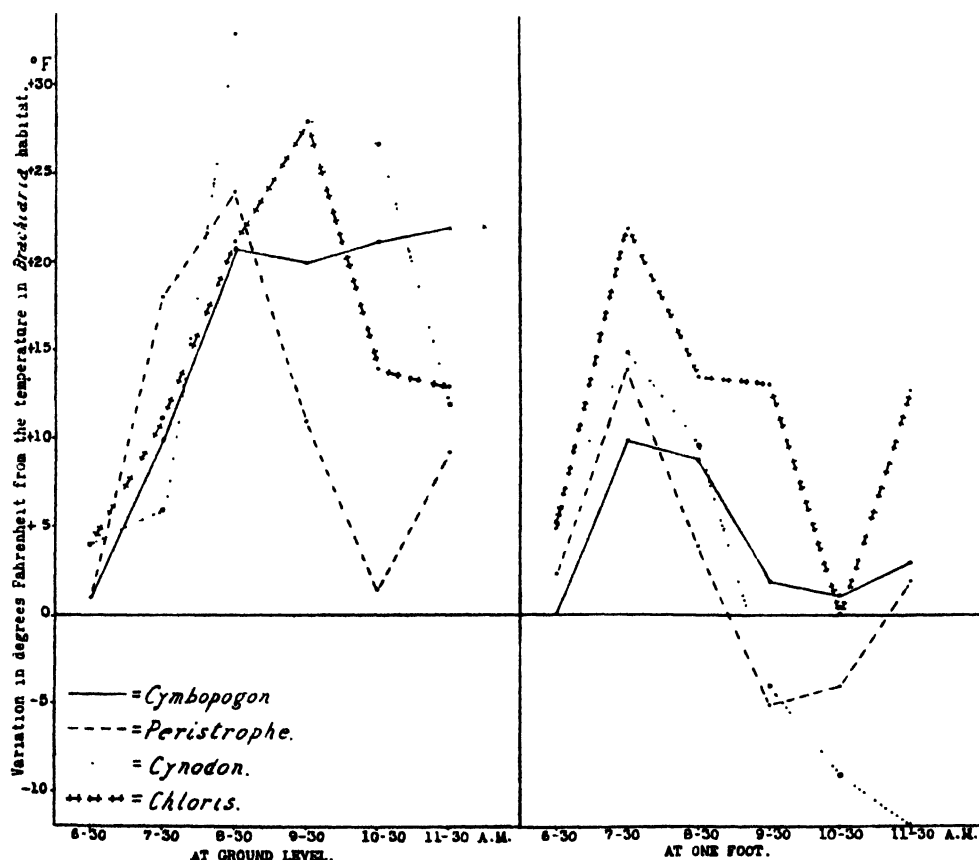


Fig. 5. Showing differences between the temperature observed in the *Brachiaria* (the coldest habitat) and in four others at the same hours of day in March.

In March, *Peristrophe* was the hottest habitat at ground-level and 1 ft. up to 8.30 a.m. and then became relatively cool. The sparse cover provided by the dead branches of *Peristrophe* would account for the relatively high temperatures in the early morning.

After 8.30 a.m. *Cymbopogon* and *Chloris* were the hottest habitats.

Comparisons of *Cymbopogon* and *Echinochloa* on 24th May and 5th June showed that *Cymbopogon* was about 3.5° hotter than *Echinochloa* from 6.30 to 8.30 a.m., and about 8° hotter during the next three hours.

A comparison of sparse and dense *Cymbopogon*, made on 29th March, showed that sparse *Cymbopogon* was from 3 to 9° hotter than dense *Cymbopogon* at ground-level between 6.30 and 8.30 a.m.

Readings taken at 1 ft. in *Cymbopogon* and *Chloris* in March, April and June showed that, while *Cymbopogon* was several degrees hotter in the first two months, *Chloris* was from 6 to 7.8° hotter after 8.30 a.m. in June. This was due to the growth of the tufts of *Cymbopogon* mentioned above.

At 6.30 a.m. the temperature was slightly lower at ground-level than at a height of 1 ft. in all habitats. During the morning the ground temperature became higher than the 1 ft. and 2 ft. temperatures; this occurred at different times in the various habitats. All the results were depicted graphically and a study of the graphs showed that the ground temperature curve crossed the 1 ft. curve between 7.30 and 8.30 a.m. in *Cynodon* and *Peristrophe*, at about 9 a.m. in *Cymbopogon* and *Chloris*, at about 11 a.m. in *Brachiaria*, and about 30 minutes later in *Echinochloa*. It is evident that the crossing time is dependent upon the density of the vegetation and the humidity of the habitat. The soil in the two wettest habitats was comparatively cool until late in the morning; while in *Peristrophe* (a dry habitat with a sparse vegetative cover) the temperature at ground-level was high some two hours after sunrise. Although the soil was thickly covered by *Cynodon*, the grass was only a few inches high and did not prevent the ground temperature from rising early in the morning.

Relative Humidity.

It was found that the relative humidity was high at 6.30 a.m., but fell rapidly during the next two hours. In the early morning the relative humidity was highest near the ground. Of five habitats studied, *Brachiaria* and *Cynodon* were the wettest and *Cymbopogon* and *Peristrophe* the driest, while *Chloris* was intermediate.

7. Notes on Fauna other than Acrididae.

Mammalia.—Hippopotami, hyaenas, jackals, three species of antelope, hares, ground-squirrels and civets, were present in the survey area. With the exception of the hippopotami, which inhabited the *Vossia* belt, all the mammals were found in *Cymbopogon* or *Chloris* during the day. The only evidence obtained of mammals preying on ACRIDIDAE was that two young jackals belonging to the writer spent most of their time catching and eating these insects near the laboratory.

Aves.—Of birds 93 species were recorded during the six months. Of these only two species, the Carmine Bee-eater, *Merops nubicus nubicus*, and the Cattle Egret, *Bubulcus ibis*, were observed to feed on Orthoptera. The Bee-eaters followed men and animals throughout the day in order to catch the ACRIDIDAE flushed from the grass. Two species of bustards, the Sudan Bustard and Senegal Knorhaan, inhabited the *Cymbopogon* belt, and a third, the Northern Black-bellied Bustard, lived in *Chloris* or dry *Brachiaria*. The bustards lived chiefly on Coleoptera, but the first-mentioned species has been seen preying on Orthoptera elsewhere in Nigeria. Two other known predators were present in small numbers, viz.: guineafowl and Abdim's storks.

Three species of snakes, monitors, lizards and several other animals were found; but no evidence was obtained that any of them preyed upon Orthoptera.

8. Bionomic Notes on Acrididae.

In the following section the incidence of nymphs, the time of oviposition and other bionomical data are discussed. Two or more colour forms of certain species were present; in these cases the incidence of the colour forms is described. Most of the species of ACRIDIDAE were rare, and it was impossible to obtain complete data by means of field observations.

ACRIDINAE.

(1) *Acrida* sp.

This species exists in three colour forms, brown, green, and green with two lateral brown stripes extending from the eyes along the edges of the pronotum and then along the hind margins of the elytra.

Nymphs, usually in the last nymphal instar, were observed in January and February. In March there was a marked decrease in number, and in early April another generation hatched. Young nymphs were seen in early May, but in June most of the hoppers were approaching maturity. Adults were present throughout the period.

Acrida sp. was found in all localities from Gusko to Wulgo. This species occurred in all the principal habitats and in *Echinochloa*, *Sorghum* and *Vossia*.

In the standard collections the brown form comprised 59 per cent. of the total number of *Acrida* taken, the green 30 per cent., and the striped 11 per cent. The following table shows the proportions of each colour form collected in three periods. In January and February there was heavy dew in the mornings, March to mid-May was a dry period, and June was humid.

TABLE VII.

Period				No. taken	Brown	Green	Striped
Jan.-Feb.	...	...	...	44	% 50	% 33	% 17
Mar.-May	...	...	...	55	77	12	11
June	...	...	...	34	40	57	3

If we divide the six main habitats into two groups, wet and dry, the first consisting of *Cynodon* and *Brachiaria*, and the second of the remaining four habitats; the following results are obtained:—

Wet habitats: brown 55%, green 33% and striped 12%.

Dry habitats: „ 75%, „ 18% „ „ 7%.

These figures indicate that the green form is associated with humid conditions. The striped form was relatively abundant in the *Cynodon* habitat.

(2) *Acridella* spp.

No grasshopper belonging to this genus was observed before 5th April; between that date and 30th June 14 adults belonging to three species were seen. Nearly all the specimens occurred in *Cymbopogon* or *Cymbopogon-Cynodon*. No nymphs were found, but two adults on 5th April and one on 10th May had recently completed their final ecdysis. It is probable that these species have an embryonic diapause during the dry season.

(3) *Aiolopus* sp. (1).

A few adults were seen in each month. Only one nymph was found, which became adult on 8th May. Specimens were taken at Gumnari, Boderi, Mafindere and Wulgo. *Aiolopus* was almost always in very wet habitats, viz.: *Echinochloa* and *Brachiaria*.

(4) *Aiolopus* sp. (2).

A very rare species only seen in early April, when adults were taken in *Cynodon* and *Chloris*.

(5) *Amphicremna scalata*, Karsch.

Nymphs, usually large, were occasionally observed in January and February ; a second generation was seen in June. Adults were found in every month except May. On 19th April adults were very numerous in the *Echinochloa-Vossia* area (the false shore of Chad), and it is evident that there was a gradual migration from the *Brachiaria* and *Echinochloa* further inland when those habitats became too dry. *A. scalata* was also found at Mafindere and Wulgo.

(6) *Calephorus* sp.

This species occurred in two colour forms, green and brown, with many intermediates showing variable proportions of both colours. A few nymphs were noticed in January and many were present in April. *Calephorus* sp. was also found at Gumnari and Mafindere.

The species was particularly abundant in the *Cynodon* habitat. The distribution of the colour forms was identical.

(7) *Duronina* sp.

The coloration of this species is very variable ; some individuals were brown and others were brown with green markings. Adults were seen up to 6th February, nearly always in the *Brachiaria* habitat. Three adults were taken at light in Maiduguri on 21st May and three at Kalkala on 18th June. On 26th June a few adults were found in *Brachiaria* and *Chloris*. It is probable that there is an embryonic diapause in the hot months, March to May ; but the species was too rare to permit examinations to be made of the ovarian condition of the females.

(8) *Orthochtiha* sp. nov.

Fourteen adults were collected between 1st January and 6th February in either *Chloris* or *Brachiaria*.

(9) *Paracinema tricolor*, Thnbg.

Occurs in two colour forms, green or brown. Adults were found throughout the period in the wettest habitats, viz. : wet *Brachiaria*, *Echinochloa*, *Sorghum* and *Vossia*. Nymphs were common in April and early May ; recently-moulted adults were observed on 10th and 25th April. Another generation of nymphs was seen in mid-June, some of which became adult at the end of the month. This species was also taken at Gusko and Gumnari. Adults frequently occurred on grass growing in several feet of water.

(10) *Platypterna* sp.

Exists in two colour forms, brownish or green ; the green form was very rare. Adults were found from 6th February to the end of June, almost always in *Cynodon* or *Chloris*. Nymphs were present throughout the same period, so it is probable that this species has an embryonic diapause, which ended in January. *Platypterna* sp. was also taken at Gusko, Boderi, Mafindere and Maiduguri.

(11) *Pnorisa squalus*, St.

Exists in two forms, the typical, and a striped form known as *P. squalus* ab. *capensis*, Wlk.

Adults occurred throughout the period. A few nymphs were collected in February and March which probably belonged to this species ; but all died before becoming adult. A gravid female was found on 10th June and two large nymphs on the 26th ; these also died before attaining maturity. *P. squalus* was recorded from Boderi, Mafindere and Wulgo.

Out of 109 adults collected, 81 were typical and 28 *capensis*. No appreciable difference in the proportion of the two forms was observable from month to month ;

but *capensis* was relatively more abundant in *Cynodon* than in the drier habitats frequented by this species. On 7th March a collection was made on old farm-land covered by three species of plants with a prostrate habit of growth, one of which was *Heliotropium undulatum*, Vahl. (Boraginaceae). Under these plants were found 24 typical form and 5 *capensis*, or about 27 per cent. of the total number of adults of this species seen in the six months.

P. squalus exhibited a greater degree of ecological plasticity than did any other species belonging to the subfamily ACRIDINAE.

(12) *Pnorisa* sp. nov.

Two types of grasshoppers were found which will probably prove to be forms of the same species. These forms correspond in coloration to those of the preceding species. Three adults of the form resembling *P. squalus* and 10 adults of a striped form corresponding to *capensis* were taken. Most of the adults occurred in *Chloris*; none was seen in February or March. One was captured at Maiduguri on 20th May. No nymphs were seen.

(13) *Stenohippus* sp.

Eight adults were taken between 7th March and 8th May. A nymph became adult on 31st March and one nymph and a recently moulted adult were found on 11th April. This species occurred in *Pulicaria*, *Chloris*, *Peristrophe* and *Cynodon*, and was recorded from Budumari and Boderi.

OEDIPOLINAE.

(14) *Acrotylus blondeli*, Sauss.

Adults occurred throughout the period; nymphs were first seen in the second half of June. One nymph became adult on 28th June. *A. blondeli* is a geophilous species and was frequently found on bare soil, it was most abundant in the *Pulicaria* and *Peristrophe* habitats. This species was also seen at Gumnari, Boderi, Wulgo and Maiduguri.

(15) *Acrotylus patruelis*, H.S.

Adults were taken at light between 23rd May and 25th June; several were present in *Pennisetum spicatum* and bean fields at the end of June. Two specimens were collected at light in Maiduguri on 21st May.

(16) *Gastrimargus africanus*, Sauss.

Four adults were seen at Maiduguri on 21st May and seven at Kalkala during June. *G. africanus* is a large conspicuous insect, and there is no doubt that if adults had been present at Kalkala before June they would have been noticed.

(17) *Morphacris fasciata*, Thnbg.

A rare species seen most frequently at light in May, after the beginning of the rains. A few adults were taken from January to March, and two or three nymphs were found in the same period which resembled the adults. *M. fasciata* was also collected in Maiduguri.

(18) *Oedaleus senegalensis*, Kr.

Adults were taken at light between 23rd May and 18th June; they were numerous in *P. spicatum* fields in late June. Gravid females were found on 26th June. This species was also collected at Mongonu, Gusko and Boderi between September and mid-November 1931, and at Maiduguri in May 1933.

(19) *Trilophidia* sp.

A geophilous species adults of which were taken in every month except April. This species was common in *Peristrophe* in January, but later was usually found on bare soil in the beanfields. No nymphs were seen.

PYRGOMORPHINAE.

(20) *Chrotogonus* spp.

Two species of this genus were present. Both nymphs and adults were numerous in January in the *Peristrophe* habitat and again in late June in the *Pennisetum spicatum* fields. Nymphs and adults were also seen in the four intervening months.

(21) *Pyrgomorpha cognata*, Kr.

This species is very variable in coloration and may be green, brown, yellow or almost white. A few adults were seen in January; they were numerous in the succeeding five months. The first nymphs were captured on 10th February; a female was observed ovipositing in hard bare soil on the 27th. Nymphs were common from February onwards; many newly-hatched hoppers were seen in early April.

P. cognata occurred in *Cenchrus catharticus*, in cotton, bean and millet fields, as well as in the main habitats. It was taken also at Wulgo, Maiduguri and Mongonu (1931).

Of 107 specimens taken in the standard collections only four were green; all four were in the *Pulicaria* habitat in April. Green adults were noticed throughout the period and were all taken either at light or in *Pulicaria*. The adults of this species captured in the drier habitats, viz., *Cymbopogon*, *Peristrophe* and *Chloris*, were all brown, yellow or whitish in colour; but six individuals in *Cynodon* also belonged to the brown group. Several specimens from dry *Brachiaria* were whitish in colour. In early March brown and green hoppers were collected from the *Pulicaria* habitat and were fed on the leaves and flowers of *P. undulata* in separate cages. Both green and brown adults were bred out from the green nymphs; but no green adults were bred from brown nymphs. It seems highly probable that the green coloration was dependent upon a supply of succulent green food and a moist atmosphere, a phenomenon observed by Faure⁵ to be characteristic of both *Locustana pardalina*, Wlk., and *Locusta migratoria migratorioides*, R. & F. The cage experiments at Kalkala were carried out at a time when the temperature of the air was high and the branches of *P. undulata*, fed to the hoppers each morning, rapidly became dry. Further, the existence of green colour forms is common amongst the moisture-loving ACRIDINAE.

(22) *Pyrgomorpha kraussi*, Uv.

This species is also comprised of green and brown individuals. Adults and nymphs occurred throughout the six months; hoppers were numerous in March and May. *P. kraussi* was also found at Budumari and Wulgo.

The first green adult was observed on 17th February; but individuals of this form did not become abundant until June. In the standard collections from January to May only 2 out of 17 individuals were green, while in June 18 out of 22 were green. Before May all the green individuals were taken in *Pulicaria*; but in May and June both green adults and nymphs were found in the drier habitats.

(23) *Poecilocerus hieroglyphicus*, Klug.

Exists in two colour forms, yellowish and whitish. This species was usually found on *Calotropis procera* and feeds on fresh and dead leaves, buds and the walls of the ripe fruits. It was sometimes seen on *Balanites aegyptiaca*, Del. (Simarubeae) and *Ricinus communis*, Linn.; the majority of the whitish specimens were captured on these plants.

From 1st January to mid-February only 9 nymphs were observed; 8 were medium-sized and 1 in the last nymphal instar. All the hoppers were comatose and none was seen in the act of feeding. In early March hoppers became more numerous and more active, being usually on the ground. At the end of March a

nymph was found underneath a plant of *Pulicaria undulata*—a favourite resort for hibernating Rhynchota, which were present in considerable numbers. The first adult was observed on 20th April, and in the following fortnight many nymphs were seen undergoing their final ecdysis. Copulation was first recorded in early June and oviposition on the 21st of that month. Very few hoppers were present after the end of April. It is probable that there is only one generation in the year and that the nymphal diapause is of considerable duration. In late July 1931, the writer saw adults of this species *in coitu* at N'Guru in north-western Bornu; no hoppers were present. On 8th October 1931, small hoppers of this species were found at Kauwa.

(24) *Zonocerus variegatus*, L.

One adult of this species was taken at Gusko on 10th October 1931. *Z. variegatus* was not present in the Kalkala area and appears to be very rare indeed in the Chad region.

CATANTOPINAE.

(25) *Acanthacris ruficornis citrina*, Serv.

The favourite habitat of this species at Kalkala was a large field of cotton in the middle of a *Cymbopogon* belt. A few adults occurred in *Cymbopogon* and *Pulicaria*. No hoppers were seen, but in late June the majority of the females captured were gravid. *A. r. citrina* was not abundant in the survey area; but occurred in larger numbers in the vicinity of Ngelewa (January 1933). In October 1931, adults were found in considerable numbers in *Cymbopogon* near Chad at Gusko; a few specimens were collected at Baga Seyoram and Shuari in the same month. Gusko was visited again in April 1933, but not a single specimen was observed.

(26) *Acorypha houi*, Ramme.

Adults occurred throughout the period in the dry habitats; they were usually seen on the soil in cotton fields, *Cymbopogon* and *Peristrophe*. Gravid females were caught in late June.

(27) *Anacridium moestum*, Serv.

The subspecific identity of the Tree Locusts taken at Kalkala has not yet been established; but from Johnston's⁷ description of the two subspecies it seems probable that both *melanorhodon* and *moestum* were present.

Tree Locusts were occasionally taken in the standard collections in *Cymbopogon* and *Peristrophe*. It was decided not to include them in the analysis of the results as their occurrence was usually dependent on the presence of small trees belonging to the genera *Acacia* or *Zizyphus*. Like many of the larger species of CATANTOPINAE they were normally found only in tall vegetation. Cotton fields, old maize and tall dead leguminous plants were favourite habitats, as was a dry thorn hedge round the laboratory. A pair was *in coitu* on 29th March; but gravid females were not found before early June. No hoppers were present and no sign of gregariousness was observed at Kalkala. In September and October 1931, Tree Locusts were common on acacias at Mufio, Mongonu and Kauwa; last instar nymphs occurred in each locality, and the final ecdysis was witnessed at Mufio on 17th September and at Mongonu on 3rd October. One hopper was brown in colour and the remainder green. There was no sign of swarming; usually there were about 12 adults on each tree. *A. moestum* was seen occasionally at Bisagana, Baga Seyoram, Gudumbari and Shuari in 1931, and at Gumnari, Wulgo and Maiduguri in 1933.

Adults were sometimes found in *Cymbopogon* and *Sorghum* belts from which trees were entirely absent.

The only substantiated record of a swarm of this species in Nigeria is from Kworre in the Sokoto Province (Lat. 13° 13' N.) on 14th January 1933. Mr. J. H. Palmer, who observed the swarm, kindly sent specimens to the writer.

(28) *Caloptenopsis* sp. (1).

Adults were very common throughout the period; no hoppers were present. The first gravid female was found on 26th May. Three adults were collected from *Sorghum* in January and one from *Echinochloa* in April; but as shown in Table V, this species was usually found in the dry habitats.

(29) *Caloptenopsis* sp. nov. (2).

Only five adults were seen, all in the *Peristrophe* habitat. Four were taken on 17th January and one on 10th February.

(30) *Cataloipus* sp. nov.

Eight adults were collected in the first week of January. None was found after that date, so that it is probable that this species has a prolonged embryonic diapause during the hot months of the year. It was taken at light on several occasions at Mongonu in late September 1931. A few specimens were collected at Bisagana, Baga Seyoram and Gusko in October 1931. On 14th November 1931, many adults were found at Dongo in a hydrophilous grass (probably *Brachiaria*) surrounding a small pool, a bush fire had recently destroyed all other grasses in the vicinity. Nearly all the grasshoppers were *in coitu*. No hoppers of *Cataloipus* have been seen by the writer.

(31) *Catantops haemorrhoidalis*, Kr.

Adults were found from February onwards in the dry habitats, being most abundant in *Peristrophe* and *Pulicaria*. On 22nd June many specimens occurred in a cotton field; one female was just about to oviposit in the sandy soil. This species was also captured at Boderi and Maiduguri.

(32) *Catantops styliifer*, Kr.

Adults were seen throughout the period, usually in the dry habitats. No gravid females were found. In late June hoppers of a species of *Catantops* hatched out in numbers; there was no time to breed them out before leaving Kalkala. It is probable that they were the nymphs of the preceding species, which was much more abundant than *styliifer*. *C. styliifer* was also collected at Wulgo and Maiduguri.

(33) *Catantops saucius*, Burm.

This was one of the commonest grasshoppers in the survey area; adults occurred in all habitats except *Cynodon*, but were chiefly found in the driest loci. Gravid females were common in the last ten days of June on bare soil in the *Pennisetum spicatum* fields and elsewhere. After the beginning of the rains there was a remarkable change in the coloration of the adults, which became generally darker. Before the rains many specimens were very light in colour; but none of this type was found a few weeks later when the humidity was higher. *C. saucius* was also taken at Budumari, Boderi, Mafindere, Wulgo and Maiduguri in 1933. On 10th October 1931, it was very common on *Hibiscus esculentus*, cotton and many other plants at Gusko; adults also occurred at Kingowa, Baga Seyoram, Shuari and Muño between September and November 1931.

(34) *Euprepocnemis* spp.

Mr. Uvarov has informed the writer that there are probably three species of this genus among the specimens sent from Kalkala, one of them being *plorans*, Charp.; separate data for each species are not available. *Euprepocnemis* spp. adults were rare after the end of January; but some were taken each month. They

frequented the *Echinochloa*, *Brachiaria* and *Chloris* habitats. Two nymphs were found on 29th April, one of which became adult on 9th May. This genus also occurred at Gusko, Mafindere and Wolgo.

(35) *Hieroglyphus daganensis*, Kr.

Two adults were recorded in early January in or near wet *Brachiaria*. Five females were found in *Echinochloa* between 24th February and 19th April; they were very worn and had undoubtedly been in the adult stage for a number of months. This species was taken at light at Mongonu in late September 1931; a pair was seen *in coitu* at Kukawa on 7th October, and many copulating pairs were noticed at Dongo on 14th November of the same year. The last mentioned couples were crowded together in the grass round a pool described above as a habitat of *Cataloipus* sp. n. No hoppers were found in either year. It seems probable that there is a prolonged embryonic diapause from November to July or later. The females observed in *Echinochloa* may have survived through having found sufficiently moist conditions to make existence possible during the dry season.

(36) *Ischnacrida* sp. nov.

Adults were common from January to June; they were never found in *Pulicaria* and only one specimen occurred in *Cynodon*. These two habitats are characterized by the relatively small height of the vegetation. This species is not very active and spends much of the day resting on grass shoots, which it closely resembles in both shape and colour. No hoppers were present; but gravid females were taken in late June. *Ischnacrida* was also found at Budumari, Boderi, Matindere and Wolgo.

(37) *Kraussaria angulifera*, Kr.

From September to November 1931, this grasshopper was observed to be one of the commonest species in the Chad area, occurring in the coastal region from Bisagana to Kalkala. At Kukawa *K. angulifera* was particularly numerous and was said to have done more damage to the *Pennisetum spicatum* crop than the Migratory Locust. It was seen usually on that crop, acacias and *Peristrophe*. A few large nymphs were recorded at Kukawa on 6th October and at Baga Seyoram on 14th October. On 9th November 1931, many adults were found dead or dying on old farm-land and in the *Peristrophe* habitat at Kalkala; a pair *in coitu* was also observed.

In the January—June survey no living specimen of *K. angulifera* was present; but examination of the soil under weeds and cotton plants resulted in the discovery of parts of the exo-skeletons of many individuals. The writer has been informed by Mr. A. M. Gwynn that *K. angulifera* was very abundant at Kalkala in mid-September. This is evidently yet another case of a prolonged embryonic diapause during the dry season.

(38) *Mesopsis laticornis*, Kr.

Adults were numerous during the six months, usually being found in the *Chloris* habitat. Hoppers were first observed in early March, another generation hatched out in June. This species showed a high degree of ecological plasticity. *M. laticornis* was present in every locality visited between Gusko and Wolgo.

(39) *Mesopsis abbreviatus*, P. B.

Very much rarer than the preceding species, only 10 adults and 6 nymphs were seen in the six months. The adults were found between 7th February and 9th May, six in *Cynodon* and three in *Echinochloa*; all the hoppers were in *Cynodon* in February, March and June. This species requires more humid conditions than those preferred by *M. laticornis*. One specimen was found at Wolgo. An individual in the very humid *Echinochloa* habitat was partly green in colour.

(40) *Ornithacris cyanea tereticollis*, I. Bol.

Adults were very numerous from January to June, especially in *Cymbopogon* and cotton fields. The height of the vegetation appeared to be of more importance than the humidity of the habitat, for this species was particularly abundant in tall *Sorghum* growing out of water in January. The other two habitats mentioned were the driest in the survey area. The habits of *tereticollis* in the *Cymbopogon* habitat were very similar to those of the Red Locust, which are described later. Copulation was first observed (at Maiduguri) on 21st May, and gravid females were found at Kalkala in early June. Oviposition took place in June; but no hoppers had hatched out by the 30th of that month.

This species was also noticed in all localities between Budumari and Wulgo in 1933. In 1931 *tereticollis* was very common—usually in *Cymbopogon*—in most of the localities visited. One last instar nymph was found at Kauwa on 8th October 1931. This species has a prolonged imaginal diapause, probably lasting from late September to early July. The only months in which the writer has not been in the Chad area are July, August and the first half of September; unfortunately this is the period when hoppers of many species of CATANTOPINAE, *i.e.*, those with one annual generation, are present.

After the beginning of the rains the adults became darker in colour.

(41) *Oxya hyla*, F.

Adults were found from 13th March to the end of June in either wet *Echinochloa* or *Vossia*. The fact that they were not encountered in the early months of the survey was probably due solely to the inaccessibility of their habitats at that time. *O. hyla* preferred more humid conditions than did any of the other species. One nymph was collected at Gusko on 29th April.

(42) *Phyxacra strenua*, Walk.

This species was first found in a cotton field on 20th June and about 15 more adults were noticed in the same habitat in the last 10 days of the survey. Regular collecting was not carried out in cotton, so it is possible that hoppers escaped notice and were present after the rains began in mid-May. *P. strenua* adults were numerous on *Guiera senegalensis*, Lam. (Combretaceae) at Marariya on 2nd July; two pairs were *in coitu*.

(43) *Spathosternum nigrotaeniatum*, St.

Two adults were taken in *Cynodon* and one in *Brachiaria* in early January. No other specimens were seen.

(44) *Thisoecetrus littoralis*, Ramb., subsp. ?.

Hoppers and recently moulted adults were found in early April. Adults were common in *Cymbopogon* and *Pulicaria* up to the end of June. Gravid females were discovered in early May, and nymphs were present up to late June. There were probably two generations of this species in the last three months of the survey. Hatching took place at the hottest period of the year.

(45) *Tristria* sp.

Exists in three colour forms, one without any green, one with green lateral stripes and the third with green on the dorsum. In the standard collections 60 per cent. of the specimens taken were of the typical form, 29 per cent. green-striped and 11 per cent. green-backed. The green-backed form was not taken at Kalkala after early March, although one specimen was found in wet *Brachiaria* at Budumari on 27th April. Adults of the remaining forms occurred throughout the period. In *Chloris*, the favourite habitat of *Tristria*, the typical form was more than three times as numerous as the green-striped form; but in the wetter *Brachiaria* and

Cynodon habitats the numbers were about equal. No hoppers were seen, and the ovaries of dissected females showed no signs of approaching maturity before 26th June. During January, 27 *Tristria* adults were collected, 16 typical form were in *Chloris*, 7 green-striped form were in *Chloris* and 2 in or near *Brachiaria*, while 1 green-backed form was in *Chloris* and 1 in *Brachiaria*. The complete absence of the typical form from *Brachiaria* suggests that the green-coloured individuals are derived from hoppers living in moist habitats. It should be mentioned that, in January, parts of the *Chloris* habitat bordering a swamp were under water. The presence of the three forms in *Chloris* may have been due to the variable conditions existing in that locus when *Tristria* sp. was in the hopper stage. After January the range of the species was increased, and individuals were taken in *Cymbopogon*, *Peristrophe* and *Pulicaria*.

Tristria was also found at Gusko, Budumari and Wulgo.

(46) *Tylotropidius* sp.

Adults were very numerous throughout the period. A few hoppers were found between early January and 2nd March. A gravid female was taken on 26th May and copulation was observed on several occasions during June. This species was very rare in the humid habitats. It was also recorded from Gusko, Boderi, Marariay and Maiduguri.

(47) *Tylotropidius speciosus*, Wlk. ?

Eleven adults were taken, of which ten occurred in dry habitats. Four were in dry *Brachiaria* and three in *Cymbopogon*. *T. speciosus* was found in January, February, April and May.

(48) *Bibulus brunni*, G. T.

The first adult was seen in *Peristrophe* on 12th June; adults were common in cotton and on the dead thorn hedge round the laboratory for the last 10 days of June. Several of the females were gravid.

(49) *Schistocerca gregaria*, Forsk.

No Desert Locusts were present in the Survey area. One adult was found at Kingowa and two at Bisagana in October 1931.

In addition to the above there were 10 very rare species present in the survey area.

Phototropism.

A record was kept of the incidence of ACRIDIDAE at light at Kalkala and Maiduguri; a week was spent in the latter town in May soon after the rains began. The Kalkala results are shown in Table VIII.

The writer was at Maiduguri from 16th to 22nd May, and many ACRIDIDAE came to light from the 17th to 21st, being especially numerous on the 21st. Most of the species mentioned in Table VIII were taken and, in addition, *Caloptenopsis* sp. (1), *Catantops haemorrhoidalis* and *Tylotropidius* sp.

The appearance at light of *Aiolopus*, *Duronia*, *O. hyla* and *Euprepocnemis*, in late May and June is of interest, as it is a certain indication that these species were migrating. Before the rains started the nearest suitable habitat for these moisture-loving species was about 1½ miles from the laboratory. Presumably the increase in humidity was responsible for the local migration. In mid-January the floods were only about 250 yards from the laboratory and the presence of moisture-loving species (including *P. tricolor*) was not necessarily an indication that migration was taking place. Three adults of *Duronia* sp. were collected at light in Maiduguri on 21st May; none had been seen since 6th February. No specimens of *Oedaleus senegalensis* were found before 17th May; from that date to the 21st they were

abundant at light in Maiduguri. On the writer's return to Kalkala he found the same species coming to light there; by the end of June adults were numerous in the *P. spicatum* fields; no hoppers were seen. An interesting instance of the effect of the rains on birds was the almost complete disappearance of indigenous species of geese and ducks from the survey area in the course of one week, viz., 16th to 23rd May.

TABLE VIII.
Acrididae taken at light at Kalkala.

Species	No. taken	Date	Species	No. taken	Date
ACRIDINAE			CATANTOPINAE		
<i>Aiolopus</i> sp. (1)	2	Jun. 18	<i>C. styliifer.</i>	2	May 23
<i>Duronia</i> sp.	1	Jan. 18	<i>C. saucius</i>	1	" 13
	1	" 20		1	" 23
	3	Jun. 18		1	" 27
<i>P. tricolor</i>	2	Jan. 18		1	Jun. 11
<i>Pnorisa</i> sp. n.	1	May 13		1	" 16
<i>Platypterna</i> sp.	2	Jun. 18		1	" 18
OEDIPODINAE			<i>Euprepocnemis</i> spp. ...	1	Jan. 18
<i>A. blondell</i>	3	May 23		3	May 23
<i>A. patruelis</i>	1	" 23		2	" 25
	1	" 28		1	" 28
	2	Jun. 18		1	Jun. 11
	1	" 25	<i>O. hyla</i>	5	May 23
<i>M. fasciata</i>	1	May 25		3	Jun. 18
	1	" 27		1	" 26
<i>Oedaleus senegalensis</i> ...	4	May 23	<i>T. littoralis</i>	1	Apr. 20
	3	" 25		2	" 21
	5	Jun. 18		3	May 13
<i>Trilophidia</i> sp.	1	Mar 27		4	" 23
	2	May 23		1	Jun. 13
PYRGOMORPHINAE			<i>Tropidopola</i> sp.	1	May 23
<i>P. cognata</i>	1	Jan. 15	<i>Bibulus brunni</i>	1	Jun. 24
	1	" 18	Unidentified sp.		
	1	" 19	No. 58	1	Jan. 15
	1	" 25		2	" 25
	1	Feb. 18		1	Feb. 18
	2	" 25		1	Mar. 27
	2	May 13		Many	May 23
	3	" 23			
<i>P. kraussi</i>	1	Jan. 28			

Temperature readings were not taken in the evening; but examination of the maximum and minimum shade temperatures and the dry bulb readings at 3 p.m. indicated that high temperatures were characteristic of the evenings on which grasshoppers were numerous at light. For instance, the minimum shade temperature on the night of 18th–19th January was 68·8°F., the highest figure recorded during that month; the second highest minimum was on the night of the 15th–16th. On 17th February the maximum shade temperature was 108·4°F., as compared with 93·0 on the preceding day; the maximum was 101·4 on the 18th, but fell to 94·0 on the 19th. On the night of 13th–14th May the minimum was 84·0 as compared

with 74.6 on the preceding night. The minima on the three remaining nights in May when grasshoppers came to light were 78.0, 81.4 and 81.6, as compared with an average of 72.1 for the month. The minimum shade temperature on the night of 11th–12th June was 80.0, the highest figure recorded in the month.

Sex Ratios.

There was not sufficient time available to enable a complete record to be kept of the sex proportions of all species of ACRIDIDAE. The following data were obtained :—*Acrida* sp.—sex ratio 594 males to 100 females ; the ratios for the three colour forms were almost identical. *P. cognata*—sex ratios of brown form 81 to 100 ♀♀, green form 15 to 100 ♀♀. *P. kraussi*—sex ratios brown form 152 to 100 ♀♀, green form 40 to 100 ♀♀.

9. *Nomadacris septemfasciata*, Serv.

In 1931 the writer arrived in the Chad area only a few days before the hoppers of this species became adult, and in 1933 he left Kalkala before oviposition had taken place. Before describing the results of his research it is desirable to give a brief account of data supplied to him by various Europeans engaged in the locust campaigns of 1930 to 1932.

Hoppers.

Hatching occurred between mid-July and mid-August each year, and the final ecdysis took place in late September and early October. The bands were sometimes of very large size, but were not usually so dense as those of *Locusta*. The principal area infested was the coastal strip between Ngornu and Mafindere ; this strip was about 8 miles wide in 1931 and some 3 miles narrower in 1930. Hoppers were generally much more numerous in 1931 than in 1930 ; unfortunately there are few data available for 1932. The majority of the hoppers were of the green *transiens* type depicted by Faure⁵ ; a few were green *solitaria* or intermediate in coloration between these two phases. In addition, on 20th August 1930, Capt. Titterington found an area of about 10 acres containing 80 to 100 clusters of hoppers ; each cluster was about 3 yards square. The hoppers were in the first and second instars and about half were green and half brownish ; the latter resembled the hopper described by Faure as ph. ? *solitaria*. The brownish hoppers formed separate clusters and were very rare in 1930 ; while in 1931, Capt. Titterington saw only one small band of this type. On the other hand, he found that the atypical green nymphs were more numerous in 1931 than in 1930 and formed about 1 per cent. of the bands. Mr. P. G. Butcher found clusters of green hoppers and clusters of brown on 21st July 1930, in the Dikwa Division ; this is the first record of the occurrence of *Nomadacris* nymphs in Nigeria. There are no records of the occurrence of phase *gregaria* in the Chad area.

The bands were usually found in long grass, viz., *Cymbopogon giganteus* or marsh grasses ; but they sometimes occurred on farm-land.

Adult Swarms.

In 1930 and 1931 swarms were seen in the first week of October close to the shore of Chad in several localities ; these consisted of individuals which had recently become adult and their flight direction was generally southwards. The occurrence of a copulating swarm near Maiduguri on 17th July 1930 has already been mentioned ; but there is no record of hopper bands being observed outside the Chad area. Capt. Titterington saw a large swarm flying southwards on 28th August 1930, and also a small copulating swarm two days later. It is difficult to explain the presence of swarms at that time in the Chad area, for, so far as is known, hatching invariably takes place before the third week of August. The writer is inclined to believe that these swarms came from another area, possibly from the Southern area mentioned

by Uvarov.¹² It will be remembered that swarms, which became mature in April in the Southern area, migrated north-westwards until July or August and then, after a time, migrated in the reverse direction. Natives in Chad say that they have known *Nomadacris* for many years and that they remember having seen hoppers in small numbers for some 20 years before 1930. They are unanimous in saying that hoppers were far more numerous in 1930 and 1931 than they had ever been before.

Distribution.

In the 1931 survey the writer found one adult at Baga Seyoram ; but none was seen in the northern part of Chad. *Nomadacris* adults were numerous at Gusko and were collected in each locality in the coastal area down to Kalkala. A swarm was seen at Shuari on 3rd November and another between Ngornu and Jerawa two days later ; the first was very scattered and the locusts were constantly changing their direction of flight, the second was resting on *C. giganteus*. Gusko was revisited in April 1933, and two journeys were made to Mafindere and Wolgo. *Nomadacris* adults were rare between Gusko and Kalkala, they were numerous at Mafindere and none was found at Wolgo—on the French Cameroon frontier. Little is known of the distribution of the Red Locust in French territory, but M. Malbrant observed very numerous and large bands of hoppers from near Massokory and from Bir-Gara to Moussoro in September 1931. These localities are from 35 to 90 miles east of Lake Chad and appear to be subject to extensive flooding in the autumn, which is presumably due to rainfall rather than to inundations from the lake.

Habitats.

During the preliminary examination of the Kalkala survey area in December and January it was found that *Nomadacris* was very abundant in the middle of the *Cymbopogon* belt to the north of the village and in *Sorghum* to the north-west of Malari. There is little doubt that swarms had settled in these two areas some months previously and had then become sedentary. Stray adults were found in *Brachiaria*, *Cynodon*, *Peristrophe* and *Chloris*. In late January the *Sorghum* plants had ceased to produce new leaves and the locusts moved to a *Cymbopogon* belt about 50 yards to the south. On 9th March it was noticed that the swarm in the northern *Cymbopogon* belt was becoming dispersed. In April *Nomadacris* was found more frequently in *Brachiaria* and *Chloris* ; in early May many adults left the *Cymbopogon* belt and scattered over the farm-land to the north-west of Kalkala. In late May, after the beginning of the rains, a similar dispersal occurred over the *Cynodon* plain to the north-east. By the end of June copulating adults were scattered over all the farm-land surrounding Kalkala and over much of the *Cynodon* plain and grazed *Vossia* to the north-east.

On 18th April it was possible to inspect an *Echinochloa* belt on the shore of Chad to the north-east of Malari for the first time. The belt was about 220 acres in area and contained large numbers of locusts, evidently members of a swarm which had settled there some months before. By the end of June *Nomadacris* was markedly less numerous in this belt as a result of a gradual movement inland. It was known that the population of the various *Cymbopogon* belts was not sufficiently great to account for the vast number of adults scattered over the farm-land, *Cynodon* and *Vossia* in late June. There is no doubt that many of these individuals were derived from areas nearer to the lake shore ; probably many came from the unexplored region beyond the *Vossia* belt.

A very dense congregation was found in *Echinochloa* and tall *Brachiaria* at Mafindere in late February. Cattle grazed down or trampled the *Echinochloa* during March, and most of the locusts had left the belt by the end of the month. In early June adults were found to be scattered over much of the country between the village and the lake shore ; they were mostly in untrampled *Echinochloa* near Chad and in patches of *Brachiaria* and *Chloris*.

Nomadacris was seldom found on grass growing in water. The central part of the *Echinochloa* at Mafindere was under water in late February and contained few locusts; the chief concentrations were found at the edges of the belt.

From the above remarks it will be seen that, during most of the prolonged imaginal diapause, *Nomadacris* lives in habitats containing tall grass. When the humidity increases, the adults leave the tall grasses and spread over the short grass habitats and farm-land. Copulation takes place in these areas and, presumably, oviposition.

It is of interest to record that *Cymbopogon giganteus* is very rare to the north of a line drawn from Baga Seyoram to Kukawa, which appears to be the northern limit of the range of the Red Locust.

Habits.

A wire gauze cage, with a cubic capacity of 268 cubic feet, was constructed and utilised for the study of the behaviour of the adults, which were fed on the leaves of *Sorghum* and *Cymbopogon*. It was found that the locusts became active in the morning when the air temperature was between 70 and 75°F. and were completely inactive at a temperature of 62°F. They were observed to rest in the shade when the temperature was 87°F.

Various grasses were introduced into the cage to determine whether the locusts exhibited a preference for any particular species of grass. There was no evidence of their preferring one grass to another. In the field they were observed feeding on *Cymbopogon*, *Chloris* and *Brachiaria*.

Observations made in a *Cymbopogon* belt showed that the locusts spent the night in the tuft of green leaves at the bases of the plants. In the morning they climbed the tall flowering shoots to dry their wings and then descended to the tufts to feed. In March, they fed until about 9.30 a.m. and then re-ascended the flower-shoots. Microclimatic observations showed that the temperature was higher at a height of 2 feet than at ground-level in the early morning when the locusts ascended the shoots in order to sun themselves; but at the time they re-ascended the shoots (after feeding) the temperature was very high at ground-level and markedly less at 2 feet.

When the adults in *Echinochloa* were found in April it was observed that they were redder in colour than those in *Cymbopogon*. Marked changes in coloration were noticed in May; the locusts in *Echinochloa* became much lighter in colour, while many of those in *Cymbopogon* were much darker than formerly, and some individuals were almost black. A similar change in colour was noticed in adults of *O. c. tereticollis* and *C. saucius*, both species becoming much darker in colour after the beginning of the rains, when they were approaching sexual maturity. A few weeks later *Nomadacris* adults of both sexes exhibited the yellow colour characteristic of sexually mature *Locusta* males; but the yellow was not of as bright a shade.

Copulation was first recorded on 20th June, and two days later the majority of the locusts on farm-land and *Cynodon* were *in coitu*. During copulation the males hold their hind femora and tibiae at right angles to the axis of the body and periodically thrust the hind-legs rapidly downwards, thus producing a noise not unlike the twang of a bowstring. The movement was too rapid to be followed by the eye; the stridulation was probably produced by the inner rows of spines on the hind tibiae passing over the surface of the elytra.

On 28th June—8 days after copulation was first observed—a few Red Locusts were seen flying in a south-easterly direction. One hour later a small swarm appeared from the east flying with the wind; a few minutes later the wind veered round to the west and the swarm returned. The westerly wind continued, and shortly afterwards many more *Nomadacris* came from the west; the swarms were not dense and many individuals settled on the ground and remained there. This was the only occasion in the six months survey when definite swarms of *Nomadacris* were observed. The habit of flying with the wind produced aggregations. This pre-oviposition flight

explains the discovery, in 1931, of hopper bands in localities about 10 miles from Chad; it was obvious that if oviposition had occurred in the coastal belt, in which the adults live during the dry season, the bands would not have had sufficient time to migrate so far from the lake before the final ecdysis took place. When travelling from Kalkala to Marte (about 12 miles to the south-west) on 1st July no *Nomadacris* were observed until the latter village was reached. Scattered individuals were found to the west of Marte which had, almost certainly, recently arrived from the coastal region. The writer had previously made four visits to Marte and had not seen a single specimen of *Nomadacris* there.

Climatic Conditions and Sexual Maturity.

Copulation was first observed on 20th June. The rains began on 14th May, 2.26 inches of rain falling between that date and the 21st. From fig. 4 it will be seen that the relative humidity at 9 a.m. rose from the week ending 6th May to the end of the period. The highest average maximum shade temperatures were recorded in the weeks ending 29th April and 13th May; but the highest mean shade temperature was in the week ending 10th June. These figures indicate that the maturation of the gonads was induced by increased humidity rather than by high day temperatures. The minimum shade temperatures from 13th May to 13th June were about 8°F. higher than those recorded in the four weeks preceding 13th May; it is improbable that the rise in night temperature was responsible for sexual maturation.

Natural Enemies.

A few Dipterous larvae were found in caged adults in January and February; the percentage of parasitism was very low and there was no evidence of mortality occurring in the field from this cause. The most important predators were the Carmine Bee-eater (*Merops nubicus nubicus*) and the Cattle Egret (*Bubulcus ibis*); many birds of both species were present in May and June in the *Echinochloa* belt, feeding entirely on *Nomadacris*.

Biometrical Data.

The wing femur and pronotum-depth head-width ratios were determined for locusts collected in 1930, 1931, 1932 and 1933. Average figures were obtained for locusts collected from a dense aggregation at Mafindere and for a number of individuals taken singly at Kalkala in 1933. The results are shown in Table IX below.

TABLE IX.

Year collected	Remarks	Number	Sex	Length of elytra	Depth of pronotum
				Length of hind femur	Width of head
1930		5	Males	1.93	1.10
"		7	Females	1.93	1.11
1931		2	Males	1.93	1.11
"		7	Females	1.98	1.12
1932		1	Female	1.99	1.10
1933	Taken singly	10	Males	2.01	1.06
"	"	10	Females	2.00	1.10
"	Taken from aggregation	10	Males	2.06	1.06
"	" "	10	Females	2.00	1.11

Although the number measured was small, the increase in the wing/femur ratio and the slight decrease in the pronotum/head ratio in 1933 as compared with 1930 show that *Nomadacris* is in phase *transiens* (*congregans*). The absence of swarms outside the Chad area indicates that the true gregarious phase has not yet been attained. It is possible that the energetic hopper campaigns of the last three years have retarded the transition from *solitaria* to *gregaria* in British Chad. It seems more probable that conditions in that area are in some way unsuitable for the production of *gregaria*.

Mr. Uvarov kindly sent the writer a female *solitaria* from Tanganyika, which has a wing/femur ratio of 1.85 and a pronotum/head ratio of 1.25. A female from Kalkala in 1931, with ratios of 1.88 and 1.12 respectively, was the only Red Locust found which closely resembled *solitaria*.

10. *Locusta migratoria migratorioides*, R. & F.

Hopper bands of this species have been present in the Chad area every year since 1930. Unlike *Nomadacris* they were found also many miles inland, and their presence in the coastal area was merely due to the fact that swarms, coming from the south, had happened to oviposit in that region. Hatching took place in mid-August in 1930 and in mid-September in the following year. There were no swarms present in the survey area until 30th May, when a swarm was observed crossing the western boundary. Five more swarms appeared between 11th and 14th June. The following data are concerned solely with phase *solitaria* or *transiens*.

Distribution.

Between 10th October and 9th November 1931, *Locusta* adults were found in all the coastal localities except Darrige and Arege; but were numerous only in a belt of *Echinochloa* close to Chad at Bisagana. A few nymphs were collected in this belt and in a "fadama" near Kingowa. In 1933 adults were found at Mafindere and Wulgo.

Habitats.

All the *Locusta* collected in the Kalkala survey area between 1st January and 25th May 1933, were either phase *solitaria* or *transiens* (*dissocians*). There is no doubt that the survivors of the 1932 hopper campaign were reverting to the solitary phase in the area. On 5th January 22 adults were found in a small area of mixed *Cymbopogon*, *Chloris* and *Cynodon*; they consisted of 16 *transiens* and 6 *solitaria*. This was the only occasion on which *Locusta* were found in a group, and it is certain that these adults were derived from the survivors of a hopper band.

The figures shown in Tables IV and V above are for both phases; the habitats in which *Locusta* was found most frequently were *Brachiaria*, *Chloris* and *Cynodon*. Analysis of the distribution of the two phases in various habitats showed that there was very little difference in the habitat preferences of *solitaria* and *transiens*. Both were found in *Brachiaria*, *Echinochloa*, *Cynodon*, *Chloris*, *Sorghum* and *Imperata cylindrica* var. *thunbergii*, D. & S. There were only four small patches of *Imperata* in the area. In January five *transiens* adults were collected from *Cymbopogon* and one from *Peristrophe*, and in April two *solitaria* were found under *Heliotropium undulatus* plants on old farm-land. Sight records confirmed the conclusion that *Brachiaria*, *Chloris* and *Cynodon* are the principal habitats of *Locusta*.

Only 14 hoppers were collected at Kalkala, all of these were found in *Brachiaria*, *Chloris*, *Cynodon* or *H. undulatum*. Two hoppers were taken at Boderi in *Cynodon* and *Diplachne* sp. aff. *fusca*, Beauv., respectively, and a third was captured in *Chloris* at Gusko.

Incidence.

Locusta was rare in the survey area and in all localities visited between Wulgo and Gusko. After the arrival of the swarms in May and early June scattered *gregaria* individuals were found in every habitat in the area.

Table X shows the number of adults of each phase caught in each month.

The last *transiens* adults were taken on 13th March. These figures prove conclusively that *Locusta* was reverting to the solitary phase. The diminution in numbers during the period appeared to be chiefly due to the Carmine Bee-eaters, which follow man and animals in order to capture the ACRIDIDÆ that fly up from the grass on being disturbed. These birds were numerous throughout the period and were often seen catching *Locusta* adults in the air. The frequent bush fires in the *Chloris* and *Cynodon* belts probably assisted in reducing the numbers of *Locusta*. Very few locusts were found in *Brachiaria* after the end of March, when the grass was becoming dry.

TABLE X.

Month	No. <i>transiens</i> (<i>dissocians</i>)	No. <i>solitaria</i>
1933		
January	37	24
February	3	11
March	3	8
April	0	7
May	0	2
June	0	1

If flying swarms had not arrived in May and June to repopulate the area, the writer is convinced that *Locusta* would have gradually disappeared from the survey area. It is evident that, each year, the descendants of the survivors of partly destroyed bands revert to *solitaria* between the months of October and March. This does not apply to undiscovered bands, which naturally leave the area as swarms. It is highly probable that the *Locusta* seen in *Echinochloa* at Bisagana were also the survivors of a band which had been partly destroyed two months before the writer's visit. The sequence of events at Kalkala and the scarcity of *Locusta* between Wulgo and Gusko in 1933 lead the writer to believe that it is unlikely that the southern part of British Chad is a reservation of this species. Further evidence on this point will be forthcoming when the present outbreak of the Migratory Locust ends.

Habits.

The first hopper was found on 21st February at Mafindere and was in the third instar; a fifth instar nymph collected at Kalkala on 3rd March became adult on the following day. Hoppers were found occasionally in April, May and June; the final ecdysis was observed to take place on 4th April and 11th May. Recently-moulted *solitaria* adults were discovered on two occasions in April; but no "young" *transiens* adults were observed. From the above data it is evident that breeding was in progress during the last five months of the survey; it is not possible to say how many generations there were in this period. In cage experiments at Ibadan (Southern Nigeria) three generations of *solitaria* were bred out in a year.

Hoppers were usually found in *Chloris* tufts or in *Cynodon*. The adults remained hidden as a rule in the early morning and did not become active until about 9.45 a.m.

Sex Ratios.

The sex ratios for *transiens* and *solitaria* were 437 and 112 males to 100 females respectively.

Biometrical Data.

Table XI shows the average measurements of males and females of both phases.

TABLE XI.

Phase	Sex	No. measured	Length of elytra	Length of hind femur	E. H.F.	Depth of pronotum
						Width of head
<i>transiens</i>	Males	35	mm. 47.29	mm. 22.57	2.10	1.04
<i>solitaria</i>	Males	28	38.94	21.37	1.82	1.25
<i>transiens</i>	Females	8	51.34	23.96	2.14	1.04
<i>solitaria</i>	Females	25	51.33	28.00	1.83	1.28

Green coloration was only observed in *solitaria* individuals. None of the *transiens* had a crested pronotum or two spots on the inside of the hind femur; but several were found with hind tibiae of a reddish colour.

Forty-three males and thirty-three females of phase *gregaria* were measured in June with the following results:—males: $2.10 \frac{E.}{H.F.}$ and $1.06 \frac{D.P.}{W.H.}$ and females: $2.19 \frac{E.}{H.F.}$ and $1.05 \frac{D.P.}{W.H.}$. It will be seen that *transiens* (*dissocians*) closely resembled *gregaria* morphologically.

Coloration.

The following table shows the general coloration of both phases.

TABLE XII.

Phase	Sex	Black	Brown	Greyish	Yellowish	Green	Total
<i>transiens</i>	00	17	17	1	0	0	35
<i>solitaria</i>	„	3	15	0	4	6	28
<i>transiens</i>	„	3	5	0	0	0	8
<i>solitaria</i>	„	1	3	9	2	10	25

N.B.—Individuals showing any trace of green coloration are classified as green.

Green adults were collected in every month except May; they were found in all the principal habitats of this species. Of 25 adults of both phases taken from the mixed *Cymbopogon*, *Chloris*, *Cynodon* habitat in early January, 23 were black or black and green and two were brown. The only green hoppers seen were from *H. undulatum* in early March.

11. Summary.

1. The shore of Lake Chad was suspected of being a reservation of both the Migratory Locust and the Red Locust. In 1931 a preliminary survey of the shore was made, as a result of which it was tentatively concluded that about one-half or less of the shore of British Chad may offer conditions suitable for the production of swarms of the Migratory Locust from the solitary phase. The Red Locust was present only in the southern half of the shore. A village named Kalkala, at the south-western corner of the Lake, was selected as the most suitable locality in which to carry out ecological research.

2. The ecology of the two species of locusts and of about 60 other species of ACRIDIDAE was studied at Kalkala during the first six months of 1933. A description is given of agricultural and climatic conditions in the Kalkala area and some notes on the hydrography of Lake Chad are included. The vegetation, soils, fauna and microclimates of the habitats frequented by ACRIDIDAE are described.

3. Collections of ACRIDIDAE were made each month in all the principal habitats. It was found that the ACRIDINAE occurred principally in the wettest habitats and that this subfamily exhibited a small degree of ecological plasticity. The OEDIPODINAE consisted chiefly of geophilous species which were most abundant on bare soil in farm-land. The PYRGOMORPHINAE were most abundant in two non-gramineous habitats, but were not uncommon in *Cynodon dactylon*; one species was associated with *Calotropis procera*. The CATANTOPINAE showed a greater degree of ecological plasticity than did any of the other subfamilies; the majority of the species encountered were most abundant in the drier habitats.

4. Bionomical notes are given for the majority of the species of ACRIDIDAE met with in 1931 and 1933 in the Chad area. Evidence was obtained that many species of CATANTOPINAE have a prolonged imaginal diapause. Certain species of ACRIDINAE and CATANTOPINAE are characterised by an embryonic diapause during the hottest months of the year, and one species of PYRGOMORPHINAE has a nymphal diapause during the early part of the dry season.

5. The Red Locust frequents tall grass habitats from November to the end of April, the adults then gradually move to short grass and farm-land and begin to breed in late June. The imaginal diapause lasts from early October to late July. Biometrical examinations of adults and other data indicate that the Red Locust is in phase *transiens* (*congregans*). There is no evidence that swarms have left the Chad area. It seems probable that conditions in this area are unsuitable for the production of phase *gregaria*.

6. The solitary phase of the Migratory Locust was present in the survey area throughout the six months; it was never numerous and decreased steadily in numbers from January to June in spite of the fact that it was breeding from late February to June. The decrease in numbers is thought to have been due, chiefly, to the attacks of the Carmine Bee-eater and to bush fires. Phase *transiens* (*dissocians*) was found until mid-March; there is no doubt that most of the locusts present were derived from the survivors of hopper bands which had been baited or trenched in the autumn of 1932. Swarms arrived in late May and early June and repopulated the area. The principal habitats of the Migratory Locust were *Cynodon dactylon*, *Brachiaria ramosa* and *Chloris gayana*. The scarcity of this species in the southern half of Chad indicated that this area is unlikely to be a reservation; but research over a number of years is necessary to confirm this opinion.

Acknowledgments.

In conclusion the writer wishes to express his indebtedness to Mr. B. P. Uvarov for identifying the ACRIDIDAE and for much helpful advice; to Sir Arthur Hill for having the plant specimens identified, and to Messrs. H. C. Doyne and W. A. Watson

for analysing the soils. The writer also wishes to record his gratitude to the Administrative officers of the Bornu Province for their valuable help in matters of organisation and to those who supplied him with information concerning the Chad locust campaigns. Mention should also be made of the good work done by the African assistants.

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-

COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st January and 31st March, 1934.

AGRICULTURAL OFFICER, QUETTA :—12 Diptera, 47 Coleoptera, 15 Hymenoptera, 4 Rhynchota, and 2 Gryllidae ; from Baluchistan, India.

Mr. T. J. ANDERSON, Government Entomologist :—2 species of Coccidae ; from Kenya Colony.

Mr. E. BALLARD, Government Entomologist :—7 Coleoptera and 2 Lepidoptera ; from Palestine.

Dr. H. F. BARNES, Rothamsted Experimental Station :—500 Parasitic Hymenoptera ; from England.

Dr. H. BLUNCK :—22 Parasitic Hymenoptera ; from Germany.

BOMBAY NATURAL HISTORY SOCIETY :—44 Curculionidae ; from India.

BRITISH NORTH BORNEO COMPANY :—25 Orthoptera ; from Borneo.

Mr. H. BRITTEN :—80 Parasitic Hymenoptera and 40 cocoons ; from England.

Dr. P. A. BUXTON :—London School of Tropical Medicine :—3 Diptera ; from Nigeria ; and 9 Tabanidae ; from Southern Rhodesia.

Mr. C. D. CAMERON :—100 Coleoptera and 7 Parasitic Hymenoptera ; from Nigeria.

CHIEF ENTOMOLOGIST, PRETORIA :—79 Coleoptera, 1 species of Coccidae, 10 other Rhynchota, and 3 Orthoptera ; from South Africa.

Mr. G. H. CORBETT, Government Entomologist :—12 Diptera, 36 Coleoptera, 200 Parasitic Hymenoptera, 2 other Hymenoptera, 20 Lepidoptera, and 4 Thysanoptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—1,130 Coleoptera ; from Kenya Colony.

Mr. A. CUTHBERTSON, Assistant Entomologist :—22 Diptera and 6 pupa-cases, 3 Coleoptera, and 5 Lepidoptera ; from Southern Rhodesia.

DEPARTMENT OF BIOLOGY, SHANTUNG UNIVERSITY :—9 Parasitic Hymenoptera ; from China.

DIRECTOR OF PUBLIC WORKS, LAGOS :—45 Isoptera ; from Nigeria.

Mr. A. P. DODD :—2 tubes of Eriophyidae ; from Queensland.

Mr. J. L. FROGGATT, Government Entomologist :—79 *Lyperosia*, 207 other Diptera, 53 Coleoptera, 33 Parasitic Hymenoptera, 7 other Hymenoptera, 13 Lepidoptera, 4 Isoptera, 1 species of Aphidae, 12 other Rhynchota, and 8 Orthoptera ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—146 Curculionidae and 96 Parasitic Hymenoptera ; from the United Provinces, India.

Mr. H. GISIN :—32 Parasitic Hymenoptera and 11 slide preparations ; from Switzerland.

Mr. F. D. GOLDING, Government Entomologist :—3 Diptera, 11 Coleoptera, 14 Parasitic Hymenoptera, 18 other Hymenoptera, 30 Lepidoptera, 1 species of Coccidae, 28 other Rhynchota, and 14 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, COIMBATORE :—3 Parasitic Hymenoptera, 2 Lepidoptera, 2 Rhynchota, and a slide of Collembola ; from South India.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—17 Parasitic Hymenoptera ; from the Punjab, India.

Mr. W. B. GURNEY :—110 Coleoptera ; from New South Wales.

Mr. E. HARGREAVES, Government Entomologist :—25 Lepidoptera, 200 Thysanoptera, 6 species of Coccidae, 40 Orthoptera, 1 tube of Mites, and 1 tube of Parasitic Worms ; from Sierra Leone.

Mr. H. HARGREAVES, Government Entomologist :—20 Culicidae, 4 Tabanidae, 6 *Glossina*, 3 Braulidae, 2 Oestrid larvae, 84 other Diptera, 257 Coleoptera, 1,400 Parasitic Hymenoptera, 708 other Hymenoptera, 450 Lepidoptera, 1,400 Isoptera, 510 Thysanoptera, 6 species of Coccidae, 11 species of Aphidae, 1 species of Aleurodidae, 4 species of Psyllidae, 361 other Rhynchota, 10 Psocidae, 3 Planipennia, 27 Ephemeridae, 3,000 Collembola, 1,500 Mallophaga, 150 Mites, 30 Spiders, 2 Chelifera, 21 Millipedes, 1 tube of Parasitic Worms, and 100 Crustacea ; from Uganda.

Mr. W. V. HARRIS, Assistant Entomologist :—21 Parasitic Hymenoptera ; from Tanganyika Territory.

Professor J. D. HOOD :—15 Thysanoptera ; from North America.

INDIAN LAC RESEARCH INSTITUTE :—500 Parasitic Hymenoptera ; from Bihar, India.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—19 Coleoptera, 2 Lepidoptera, and 6 Rhynchota ; from the Dutch East Indies.

Mr. C. A. ISAAKIDES :—7 Parasitic Hymenoptera ; from Greece.

Miss D. J. JACKSON :—6 Parasitic Hymenoptera ; from Scotland.

Mr. W. F. JEPSON :—4 Diptera and 2 pupa-cases, 25 Coleoptera, 18 Hymenoptera, and 20 Mites ; from various localities.

Dr. W. A. LAMBORN :—130 Culicidae and 5 other Diptera ; from Madagascar.

Dr. R. H. LE PELLEY, Assistant Entomologist :—2,000 Parasitic Hymenoptera ; from Kenya Colony.

Mr. D. J. LEWIS, London School of Tropical Medicine :—5 Diptera, 22 Rhynchota, and 2 Orthoptera ; from Nigeria.

Mr. R. MAYNÉ :—28 Coleoptera ; from Colombia.

MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS :—2 Parasitic Hymenoptera ; from France.

Mr. H. D. NANGPAL :—37 Parasitic Hymenoptera and 2 Lepidoptera ; from Cawnpore, India.

Mr. J. DE B. R. QUEIROZ :—5 Coleoptera ; from Angola.

Mr. Y. R. RAO :—100 Orthoptera ; from Karachi, India.

Dr. W. E. RIPPER :—21 Parasitic Hymenoptera ; from Austria.

Mr. T. A. RUSSELL, Plant Pathologist :—4 Coleoptera and 30 early stages, 50 Parasitic Hymenoptera, 15 Thysanoptera, and 2 species of Coccidae ; from Bermuda.

NIHAT SHEVKET BEY :—75 Coleoptera and 11 Orthoptera ; from Asiatic Turkey.

SELANGOR MUSEUM :—1,235 Coleoptera ; from Malaya and Borneo.

SENA SUGAR ESTATES :—20 Coleopterous larvae and 100 Orthopterous eggs ; from Portuguese East Africa.

Mr. L. F. DE SEQUEIRA :—21 Culicidae and 8 slide preparations, 14 Tabanidae, 13 other Diptera, 7 Ticks and 4 slide preparations, and 3 slides of Mites ; from Portuguese Guinea.

Mr. H. W. SIMMONDS, Government Entomologist :—5 Diptera, 41 Coleoptera, 117 Parasitic Hymenoptera, 60 other Hymenoptera, 59 Lepidoptera, 50 Isoptera, 34 Thysanoptera, 10 species of Coccidae, 2 species of Aphidae, 50 other Rhynchota, and 3 Orthoptera ; from Fiji, etc.

Mr. H. D. SMITH, European Parasitic Laboratories :—2 Parasitic Hymenoptera ; from France.

Mr. E. R. SPEYER :—1 Erotylid ; from South America : and 3 Parasitic Hymenoptera ; from England.

Mr. J. SUIRE :—57 Parasitic Hymenoptera ; from France.

UNITED STATES NATIONAL MUSEUM, WASHINGTON :—2 Parasitic Hymenoptera ; from North America.

Mr. R. VEITCH, Chief Entomologist :—3 Rhynchota and 2 early stages ; from Queensland.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—180 Culicidae, 16 Tabanidae, 70 other Diptera, 198 Coleoptera, 114 Parasitic Hymenoptera, 43 Rhynchota, 2 *Bittacus*, and 7 Scorpions ; from the Sudan.

Mr. W. WELLMER :—250 Parasitic Hymenoptera ; from Germany.

Mr. W. E. WHITEHEAD :—4 slides of Mallophaga ; from Canada.

THE BIONOMICS AND IMPORTANCE OF *GLOSSINA LONGIPALPIS*, Wied., IN THE GOLD COAST.

By K. R. S. MORRIS, Ph.D., B.Sc., A.R.C.S.

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1. Introduction.

Glossina longipalpis, Wied., is undoubtedly of great importance as a vector of human and animal trypanosomiasis in West Africa, and yet of all the commoner species of tsetse-flies it seems to have received the least attention and the least amount of study. Its distribution extends from French Guinea in the west to the Cameroons in the east, and southward through the Belgian Congo into Angola. In places it forms fly-belts of considerable density, and Roubaud (1920) considers it as among the four important species of *Glossina* in French West Africa. It occurs in numbers within eight miles of Accra, the capital of the Gold Coast (Macfie, 1923), but no serious study seems to have been made of it, and nothing has been written on its exact significance as a vector of the pathogenic trypanosomes, or of its exact distribution and relationships with its environment.

The writer became casually acquainted with *G. longipalpis* while working in the Northern Territories of the Gold Coast in 1929 and 1930, and from February to September of 1931 carried out a detailed study of certain points in its bionomics at a fairly heavily infested fly-belt in the neighbourhood of Takoradi on the Coast. The Tsetse Investigation in the Gold Coast was unfortunately discontinued after September 1931, leaving a great deal of this work incomplete. It seems a pity, however, to waste such results as were obtained, and these, and the conclusions drawn from them, are set down in the following paper.

2. The Country round Takoradi.

Takoradi lies on the sea-coast in the Western Province of the Gold Coast Colony, and has attained considerable importance since the construction there of a large harbour, opened in 1928, making it the terminus of the Kumasi-Sekondi Railway and principal port for the Colony. Previous to the building of the harbour there were merely one or two tiny villages on this part of the Coast, Sekondi, seven miles to the east, being the Provincial headquarters, railway terminus, and commercial port.

Geologically, the country consists of a series of irregularly faulted beds of mudstones, sandstones, shales, grits, and conglomerates, dipping normally to seaward, but through so much faulting the dips vary greatly in direction and amount. This

gives the country an undulating character, numerous small ridges and hills, 50 to 100 feet in height, alternating with long narrow valleys. Here and there, especially round the lower reaches of rivers and lagoons, are large marshy flats.

The vegetation of this country is transitional between Evergreen Rain Forest and Savannah Forest (Chipp, 1922, p. 13). The former lies within 20 miles to the north and extends right down to the coast at Axim, 40 miles west. Coastal Savannah stretches from just beyond Sekondi eastward. This Transition Forest is of an extremely dense nature, which is probably resultant upon the activities of the local natives, who are, naturally, primitive hunters and fishermen and very poor agriculturists, following a shifting system of cultivation in which farms are abandoned after one or two years' use. The succeeding growth of secondary bush is essentially of a small tree type, with tall trees here and there, but is, in the main, of an extremely dense, impenetrable nature. This grows right up to the villages, which usually have no extensive farms or clearings round them, farms under cultivation being scattered at irregular intervals throughout the bush. In this forest the oil-palm, *Elaeis guineënsis*, Jacq., is the most noticeable species, sometimes forming almost pure stands over small areas. Of other species the following were identified, but the composition varied so from place to place that it was impossible to assign dominance to any one species or group of species:—*Alchornea cordifolia*, *Terminalia* sp., *Elaeis guineënsis*, *Bombax* sp., *Conopharyngia Jollyana*, *Pandanus candelabrum*, *Pentaclethra macrophylla*, *Triplochiton Johnsoni*, *Pycnanthus Kombo*, *Myrianthus arboreus*, and *Musanga Smithii*. This very dense bush gives place along the valley bottoms to small open glades, with few scattered trees and coarse grass not more than two to three feet high even in the height of the rainy season. It must be borne in mind that such open glades are very small in extent, some 50 to 100 yards across, and of variable length, their proportionate area being about one-fifth to one-tenth that of the bush. The vegetation here is never dry, and never burned, and during the rains the glades are rarely flooded. Quite distinct are the flat, open marshes, which occupy large continuous areas, support only a coarse grass flora, are usually flooded in the wet season and parched in the dry season, although not burned in this part of the country.

This coastal belt of Transition Forest holds a surprisingly rich fauna, differing very little from that of the Evergreen Forest. Of the ungulates, the bushbuck (*Tragelaphus scriptus*, L.) is probably the commonest, but several species of duiker are abundant. The black duiker (*Cephalophus niger*, Gray), the blue duiker (*C. maxwelli*, Smith), and the gray duiker (*C. brookei*) were identified. Bush pig (*Choeropotamus porcus porcus*, L.) are plentiful, more especially in the quieter parts of the forest. The West African race of buffalo (*Syncerus caffer*, Lyd.) occurs in at least one locality within fifteen miles of Takoradi. Leopards (*Panthera pardus*) are present in the Evergreen Forest and in the remoter parts of the Transition Forest. Serval (*Felis serval*) are quite common, even close to the villages and towns. Monkeys are everywhere abundant; *Colobus polykomos vellerosus*, Geoffroy, appeared to be the commonest species. Of rodents, the large bush rat (*Cricetomys gambianus*, Waterh.) and the cane rat (*Thryonomys swinderianus*, Tenn.) are ubiquitous, preferring the marshy hollows. Fruit bats, mainly *Eidolon heloum*, Kerr., occur everywhere. Snakes are abundant, and the land varanus is found, especially near rivers, in the larger of which crocodiles are fairly plentiful.

Three species of *Glossina* have been found in this coastal area. *G. longipalpis*, Wied., is by far the commonest and most widely distributed, occurring everywhere in the zone of Transition Forest, right up to the villages and towns, but never extending its range into the Evergreen Forest. *Glossina palpalis*, R.-D., is plentiful along the courses of the rivers and streams, but only found as an occasional wanderer away from these. *G. medicorum*, Austen, was found both in Evergreen Forest and in Transition Forest, but was nowhere abundant. Partly because of the scarcity of the latter two species at Takoradi itself, but mainly in order to make the study the more

full and complete, the writer confined his attention entirely to *G. longipalpis* when "tsetse" or "fly" are mentioned in this paper, it will always refer to that species.

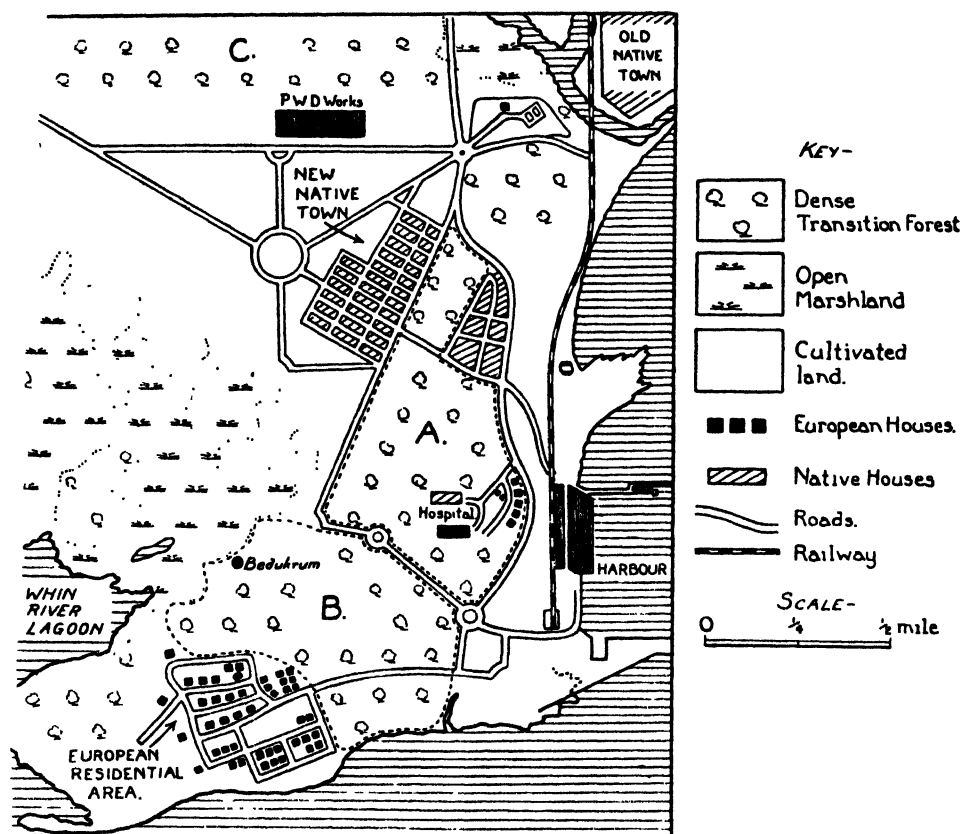
The most noticeable feature of the climate of this coastal area is its remarkable uniformity throughout the year; there is no wide range in temperature or humidity, the very seasons merge gradually one into the other and lack that marked contrast between wet and dry season which is such a feature of Inland Savannah. There is a long dry season, lasting from December to the beginning of March, during which rain occasionally falls, but in very small quantities, the total rainfall averaging one inch or less a month. In March the main wet season begins and continues until May, the greatest precipitation being normally in May and June, when 8 to 16 inches of rain may fall in a month. August and September usually show very little rain, an abundance of sunny days, and make up a short dry season. In October and November is a second or short wet season, but the rainfall is slight, three or four rainy days with a total of from one to two inches a month. The annual rainfall is between 40 and 45 inches. The monthly mean shade temperature in the long dry season varies from 80°F., and the monthly maximum falls just below 88°F. The temperature rises somewhat in March and April to 82°F. monthly mean, and 90°F. to 94°F. monthly maximum. In August the lowest figures are recorded: 74°F. mean, and 79°F. maximum for the month. From now the temperature rises steadily to the dry season figure in December. When considering the relative humidity, the greater uniformity is encountered, the mean monthly relative humidity never falls below 75 per cent. in the height of the dry season, and rising to 80 per cent. in June, just after the height of the rainy season. The climate of Takoradi itself, and of the fly-belts, will be considered in detail in a later section when discussing its influence on the activity and density of the tsetse population.

3. The Study of *Glossina longipalpis* at Takoradi.

When Takoradi was first visited at the end of February 1931, it was found that a considerable area of thick bush (A and B on the large-scale map of Takoradi, Map 1) had been isolated by natural and artificial boundaries from the remainder of the bush which stretches away more or less continuously to the north and west of the town, as shown on the map. The flora of this bush is identical with that of the Transitional Forest of this coastal area, already described, and the area constitutes a permanent fly-belt of *G. longipalpis* and is isolated from any surrounding fly-belt by sea to the south and east, by the Native Town to the north, and on the west by an extensive stretch of open marshland. A well-used, wide road divides this fly-belt into two areas, marked A and B on the map, equal in area, each covering approximately 20 acres. In the centre of Section A stands the Takoradi Hospital, in a clearing of approximately 20 acres. One unoccupied building of this hospital was used as a laboratory for this work. In section B was one small native village, Bedukrum, only six huts and with practically no clearing. Constant observation showed that there was no marked migration of tsetse into or out of this fly-belt, and there was very little movement of flies between A and B. Both the areas were free from native intrusion; B because of its proximity to the European residential area, and A because of the Hospital. A few small farms were broken here and there, and there was occasional cutting of firewood, but apart from this there was singularly little disturbance of the bush, as was well demonstrated by the fauna it maintained, which comprised all of the animals mentioned in the preceding section, with the exception of buffalo, leopard, and crocodile. It will be seen that here was ideal material for the study of a tsetse community, isolated from any large fly-belt, but otherwise, as far as could be judged, normal.

Continuous meteorological observations were kept from March to September. The Harbour-master of Takoradi very kindly supplied copies of their meteorological

monthly, from which figures for sunshine and rainfall were taken. Shade temperature and relative humidity were taken with a whirling hygrometer at three times daily, between 8.30 and 9.0 a.m., which was found to be the time of maximum activity of *G. longipalpis* in March. The stations were (i) in the shade of a small Acacia tree in the open clearing by the Hospital, 200 yards from the tsetse bush; (ii) in the dense bush on comparatively dry ground; (iii) in the bush on the edge of one of the small glades in a valley bottom. The readings were always taken at a height of about three feet from the ground, the height at which the flies are most commonly observed flying or resting. The readings of stations (ii) and



Map 1. Takoradi.

were found so uniformly identical, or nearly identical, that in the subsequent analysis of the data only stations (i) and (iii) will be considered, as representative of the "open" and the "fly-belt." During part of August and three weeks of September, hourly readings with the whirling psychrometer were taken from 6 a.m. to 6 p.m. in the shade, this being correlated with the tsetse catching. From 1st May readings of the absorptive power of the air were taken with two sets of Livingston-thorne atmometers, one at station (i), representative of the "open," the other at station (iii) in the valley bottom, representing the "fly-belt." Further, observations on the wind and the state of the clouds were noted daily.

The estimation of the flies' density-activity was always carried out on an hourly basis, by teams of two trained "fly-boys," each in charge of either the writer or a

thoroughly reliable native clerk. A team worked for six hours a day, from 8 to the morning and 2 to 4 in the afternoon, and in this time could make a very tentative catch of the whole of the areas A or B. Definite fly-rounds were not allowed, the boys taking different paths or game-tracks through the bush each but always visiting two or three open glades in each area. The boys proceeded slowly and made frequent halts, when the surrounding bushes and undergrowth examined closely for resting flies, or were slightly stirred and the flies caught as flew out. More flies were caught in this way than were caught coming to feed; this species was never found to feed very readily upon human hosts. At the end of each hour the flies were counted and the sexes noted. From the middle of May until the end of September catches were made daily in section A, and four or five times a week in section B. All the flies caught in A were brought back to laboratory and killed at the end of each day, but in B catching and letting go maintained the whole time, the total catch being liberated in the bush after it was counted up at the end of the day. This section then was regarded as the control area for the experiments. During a week at the end of August and two weeks in September, catching in B was continued daily for 12 hours a day, and at the same time an hourly reading of shade temperature and humidity was made at the place of catching. Two teams of boys were employed for this, one working from 6 a.m. until noon, the other from noon until 6 p.m. In the subsequent analysis the density-activity figures for area B are kept strictly comparable by considering only the numbers of flies caught between the hours of 8 and 12 a.m., and 2 and 4 p.m. throughout the whole period. An estimation of the flies' movements out of the fly-belt into the open was made by collecting daily all the flies round the hospital buildings. This indicated a movement of the flies across from two to four hundred yards of perfectly open ground. At the beginning of the investigations a third area, Section C, was chosen as representing a section of fly-belt equal in every way to sections A and B, except that it was continuous to the north and west with a very much larger uninterrupted fly-belt. Soon after routine catching was commenced here much of the land was cleared and broken for farming, and subsequently planted mainly with cassava, and the rest of the bush was constantly being cut for firewood by natives. Throughout the time of these investigations in Takoradi its excursions were made, once or twice a week, into the surrounding country, and sample catches were made under the same conditions as were being observed in Takoradi. Such excursions covered roughly the area between Axim, to the west and Shama, at the mouth of the Pra River, to the east. These catches were found to be comparable, to follow fairly closely the fluctuations in the tsetse population in Section B, though usually showing a higher count, but the difference was not so great that these areas A and B might not be taken in every way, except in the isolation, as typical samples of the great fly-belt of *Glossina longipalpis* stretching along the coast from Axim to Accra.

4. The Food of *G. longipalpis* and its Influence on Distribution.

Many observers have remarked upon the association of *G. longipalpis* with game (Frew, 1929), more usually with the larger species, such as buffalo (De Almeida Rebelo, 1927) and hippopotamus and elephant (Roubaud, 1911). Throughout the whole of the coastal fly-belts large game animals are conspicuous by their absence; only one or two small herds of buffalo existing in the denser and quieter bush on the western side. In the Takoradi fly-belts the species of game were limited to four, the bushbuck and the three species of duiker, *Cephalophus niger*, *C. maxwelli*, and *C. brookei*, and from several lines of evidence it has been deduced that these animals constitute the main source of food for fly. Firstly, of the limited number of available food hosts several may be eliminated straight away. Reptiles and birds may be dismissed, as in about 500 examinations of stomach contents of *G. longipalpis* only mammalian blood was ever found, being recognisable in 23 per cent. of the stomachs

observations while catching, man is certainly not a favourite host, being bitten when the fly is very hungry and other food is scarce, wherefore he cannot be relied as a natural or regular food supply of this species. Of the other mammals in the neighbourhood of Takoradi, bush-pig and serval were very rare and only nocturnal, and so may be ruled out. In experimenting with tame monkeys, tsetse was always caught and eaten before it could bite. The extremely active alert wild monkeys could only be fed upon when asleep during the day, and such lions are rare. There still remain the cane-rats and bush-rats, so common in the open valleys, and although the habits of these animals, keeping, as they do, in the cover of the low thick herbage, renders them unlikely to be attacked by the higher-flying tsetse, this is not sufficient to exclude them from the flies' diet. There is, however, another line of evidence arising out of the sequence of events in section C, here, as has already been mentioned, an area of normal fly-belt was broken up during the course of the summer for farms and firewood. The first effect of this cutting and clearance of the bush was to drive away the larger animals, the bushbuck and kudu. This was further hastened by the native hunters, who harass the game day and night over most of the country round Takoradi, but who did not hunt in sections A and B. In March, when section C was first visited, one or two bushbuck and many tracks of duiker, and the fresh tracks of a bush-pig were seen. From May onwards no single game animal was seen in this area, despite visits by both day and night, and none was shot here by natives after the middle of May. Of the smaller animals, monkeys were frequently seen raiding the farms by day, and rats were quite common, especially in some marshy hollows at the back of the Public Works Department works. The bush was by no means entirely removed, ample cover of uncut trees remained, and the temperature and humidity was not markedly lowered in comparison with that prevailing in the control area. Yet by the end of May tsetse were practically absent from this area, whereas in March the fly-catches had been but a little lower than those in the control area, as can be seen from Table I.

TABLE I.

Average daily catches of G. longipalpis in Areas where Game was undisturbed and where Game was driven away.

	March	April	May	June	July	August	Sept.
Section B. (1) ...	60	68	77	51	50	35	46
Section C. (2) ...	52	40	15	0	7	0	0.3

(1) Undisturbed control area. (2) Game driven out.

It might be argued that a seasonal migration of the fly had taken place in the neighbourhood of section C which could not take place in the isolated areas A and B. For such a migration to account for the absence of the fly from C, it would have to be movement from the periphery of the bush inwards, but such movement as did actually take place during the summer was the very reverse, an outward movement of the fly from the denser bush towards and into the open country. It is evident, then, that in this region *G. longipalpis* can maintain itself entirely upon the smaller antelopes, bushbuck, and duiker, as food hosts and these are of such importance to it that their removal is followed by the dispersal of the fly.

It seems appropriate to discuss here the distribution of the fly within the fly-belt, especially the distribution of the sexes, as this seems influenced mainly by food. In vegetation of such a homogeneous nature the fly was found to show a fairly uniform distribution as regards density, but in sex proportions the largest numbers of female flies were caught in the glades and valley bottoms, around isolated farms containing growing crops, and, in the wet weather, round the edges of the forest and outlying

patches of bush in the open marshes. The percentage of females in the catch of the whole area varied from 2 to 18 per cent., according to the season, the latter figure being recorded at the beginning of June, and the lowest figure in July. 10 per cent. represented the normal figure for the year. When catching in and around the open glades, a very large proportion of females was always obtained, up to 60 to 70 per cent., and catches made in the open, either round the hospital or in the European residential area, or in the large open places in the remoter bush, yielded an equally high female percentage. There is no doubt, then, that the more open parts of the bush, especially the grassy glades and small discontinuous farms, are the principal feeding grounds of *G. longipalpis*, and are, moreover, the places especially frequented by bushbuck and duiker in the early morning and late evening. The observation that small isolated patches of farm in the bush, once under crops and therefore infrequently visited by natives, form female concentrations of *G. longipalpis*, was frequently confirmed and is of special importance, especially when it is seen what an effect continuous and extensive farming can have, as in section C. This will be discussed in the section on the control of the fly.

5. Breeding.

According to Mr. A. W. J. Pomeroy, the Medical Entomologist, who had been investigating other entomological problems at Takoradi previous to the writer's arrival, no breeding of *Glossina longipalpis* took place throughout the dry season. Certainly in February no living pupae could be found, no pregnant females were caught, and there were no young flies in the daily catches. Judging by the number of pregnant females in the catches made in section A (the section from which flies were brought back to the laboratory for dissection), breeding commenced at the end of March and increased gradually through April to a maximum at the end of May.

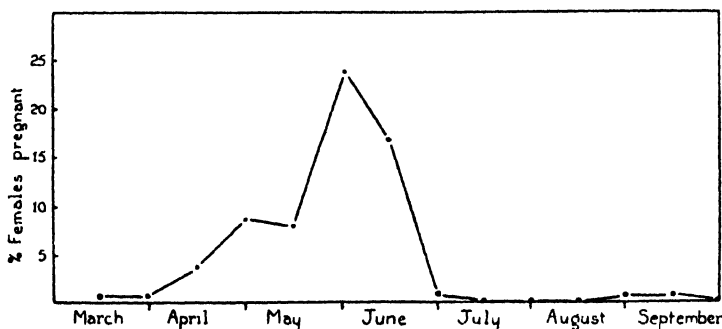


Fig. 1. Percentage of pregnant female *Glossina longipalpis* from fly belt A. Takoradi, 1931.

During the first two weeks in June there was a slight falling off in the numbers of pregnant females, though at this time there was the largest proportion of young flies in the catch, just under 8 per cent. At the end of June there was a sudden cessation of breeding, which lasted until September, when there was a just perceptible increase in breeding activity. The proportion of young flies dropped in July and August to less than 2 per cent., but by the end of September had risen to 3 per cent. Fig. 1 represents graphically the percentage of pregnant flies found in this area. The figures are based on an average of 150 female flies examined monthly, except for June, when a very low percentage of females was caught, and only 80 females were examined, and August and September when the numbers were 66 and 103 respectively.

The small percentage of females found pregnant, even at the height of the breeding season, is rather surprising in view of the high percentages, up to 80 and 90 per cent., that are recorded among catches of other species of *Glossina*, especially in East

rica. It must be remembered that this fly is very loath to feed upon humans, therefore the unconscious selection of non-pregnant females by the catchers, which cures at all times, is intensified in the case of *G. longipalpis*. Comparatively few of the flies were caught coming to feed upon the fly-boys, therefore it is natural that pregnant females when they do feed, tend to select the favourite antelope food and would otherwise be seldom encountered. Pupae were found only in May and June, and then in very small numbers, which was mainly due to the scattered nature of the breeding sites. In such close proximity to a town, fallen logs and tree-trunks are quickly removed by natives, and the only sites where pupae were found were round the bases of thick, old palm trees (*Elaeis guineensis*), whose fallen branches form a sort of tent, giving good shade and shelter. Even in such places only one or two pupae were ever found at one time. It seems, then, that in this locality there is only one short breeding season during the year, its maximum occurring at the height of the long rainy season, but this is followed by a sudden and almost complete cessation of breeding.

6. The Influence of Climate.

The methods employed in studying the climate of Takoradi, both within and without the fly-belt, and in studying what must, for the moment, be called the "density-activity" of the tsetse, have already been outlined. In this way continuous observations extended over 26 weeks for fly numbers, rainfall, sunshine, temperature, and humidity of the open, and for 20 weeks for temperature and humidity of the fly-belt. In approaching the subject of the relation of the density-

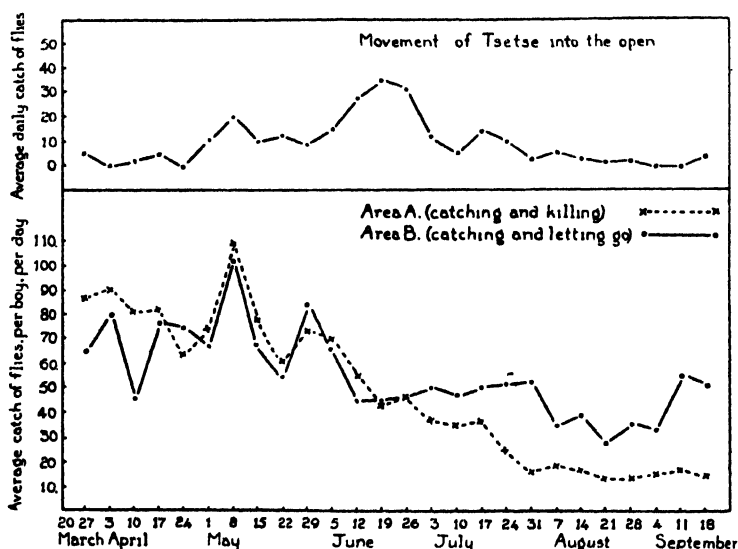


Fig. 2. Density of *G. longipalpis*, shown by the average daily catch per boy, in two fly belts. A and B, at Takoradi. Above: movement of the fly out of the fly belts into the open, 1931.

activity to these climatic factors, the daily observations have been grouped into weekly periods in order to eliminate, so far as possible, individual errors and variations, and obtain a general picture of the fly's reactions. These weekly periods consist, in the case of meteorological data, of averages of seven observations, in the case of fly catches of averages of four, five or six catches a week. There is some difficulty in selecting a method of expressing the humidity of the air. Readings of atmometer evaporation certainly have advantages over expressions of relative humidity or

saturation deficit, in that they should, theoretically, represent far more closely evaporative power of the air to which the fly is actually exposed in nature ; secondly, they certainly sum up the total effect over the whole period between observations. At the same time the atmometer does not give readings of any physical constant ; it sums up, in reality, the combined effect of wind, temperature and the existing air humidity, and it is probable that wind is the most influential of the three factors. In attempting an analysis of climate, then, the atmometer falls between three stools, and it is desirable, for a number of reasons, to be able to express the humidity of the air in physical terms. Undoubtedly, the best notation to use for this purpose is that of saturation deficit, since an insect's loss of water in air is more closely related to this than to relative humidity. As, however, practically all general meteorological data on humidity are expressed in the relative scale, the writer will frequently quote this notation, as it will be necessary, later in the paper, to refer to meteorological statistics of the Gold Coast. Actually, over the small range of temperature encountered during the work, the divergence between relative humidity and saturation deficiency is not very great.

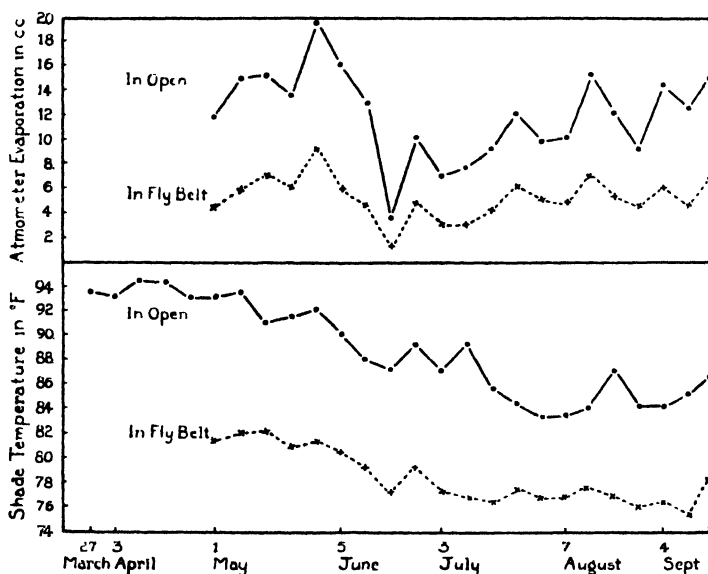


Fig. 3. Average daily rate of evaporation and 9 a.m. shade temperature in the fly-belt and in the open, Takoradi, 1931.

The density-activity of *G. longipalpis* is shown graphically in Fig. 2. Shade temperatures and atmometer evaporation in the fly-belt and in the open are represented in Fig. 3, and sunshine and rainfall in Fig. 4. In Fig. 5 are shown the relative humidity and saturation deficiency of the fly-belt, and relative humidity as taken by a wet and dry bulb hygrometer in a Stevenson screen in the open. In examining the graph of fly density-activity, the first thing that draws the attention is the marked diminution in the numbers of flies caught in section A, where the daily catch was killed, in comparison with section B, where the flies were liberated at the end of the day. It has been emphasised above that conditions in A and B were identical throughout the experiment, and therefore this drop in density-activity must be the result of catching alone, and for this reason must be regarded as a definite reduction in the tsetse population, not a variation in activity, such as might accompany changes in climate, food supply, or habitat. There is a noticeable flattening out of the curve accompanying this reduction in population, and there is no sign of the recovery in

bers which takes place in section B in September. At this time, the density in A is less than one-third of that in B, and it seems quite justifiable to expect that, had it been possible to carry the experiment further, the reduction in numbers could have continued and eventually the tsetse population of A would have been seriously affected.

A study of Figs. 3 and 5 gives a good idea of the climate within the fly-belt, the "ecoclimate" of Uvarov (Uvarov, 1931), as compared with the general climate of the open country. In Fig. 5 the curves of relative humidity are included mainly for the purpose of assessing the value of figures obtained under standard conditions, such as obtain in all the agricultural stations of the Gold Coast, as compared with those obtained by the more accurate whirling hygrometer within the ecoclimate itself. It is evident that the former readings, inaccurate though the stationary wet and dry bulb hygrometer may be, do bear a sufficiently close relation to the humidities of the fly-belt, and it will be demonstrated later that they show a definitely significant coefficient of correlation to the activity-density of the fly, so that it is certainly justifiable to utilise standard meteorological data of relative humidity for such purposes.

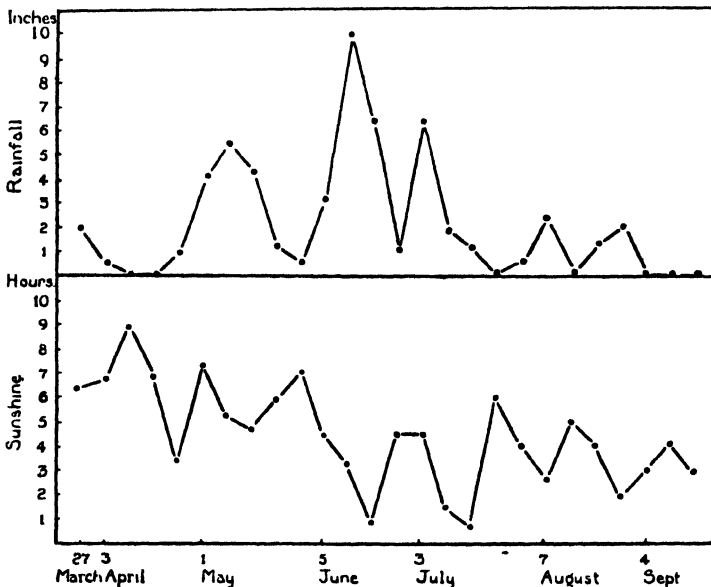


Fig. 4. Average daily rainfall and hours of sunshine at Takoradi, 1931.

as a general analysis of the climate of tsetse-infested country, or a forecast of tsetse distribution. Turning to temperature and evaporation, the more equable climate of the fly-belt is apparent, besides the consistently lower figures for both of these factors. During the period of observation, temperature in the fly-belt shows only a 7°F. range against a 10°F. range in the open, and the fluctuations are not so abrupt. In evaporation the contrast is more marked, the fly-belt showing a variation of 8 cc., whereas the open varies over 16 cc. Although the temperature of the open never fell within the range of fly-belt temperatures, yet evaporation in the open, during the heavy rains in June, fell to the very low figure of 3.8 cc., well within the average evaporation rate in the fly-belt. It is noticeable that this coincides with the greatest catch of tsetse in the open, in the third week in June, as shown in Fig. 2. Now such a movement of fly into the open, really an extension of range from its primary fly-belt into less suitable environments, usually takes place when the fly population of the bush is at its maximum density. In the case in point, this should have occurred in May, when in actual

fact the number caught in the open was half of that occurring in June. This movement of the flies must be due to the most suitable climate of the open at this time, rather than to pressure of numbers within the fly-belt, and the significant factor of the climate is evidently the evaporating power of the air in the open, high in May but low in June.

For a further understanding of the fly's reactions to climate, it is necessary to study the behaviour of the fly in the control section B. There is evidently a general positive correlation between the tsetse's density-activity and temperature, and also saturation deficit of the fly-belt. The correlation with relative humidity is, of course, negative. The atmometer readings again, though not so obviously, seem to have a general positive correlation. The effect of rainfall is more difficult to estimate. The heavy rains of early May are accompanied by a peak in the fly's numbers, but during the heavier rains in June and July there is a great drop in numbers, which persisted until the end of the rains, when a slight recovery commenced. The time when the fly's density-activity was at its lowest does not correspond with the heaviest rainfall or the greatest humidity, but is coincident with the greatest fall in temperature. The influence of sunshine is also rather obscure, and if there is any deficit, it is possibly immediate and temporary, acting upon the activity of the fly. This would also be the influence of heavy showers of rain, apart from the general effect of rainfall in raising the air humidity. These immediate effects on activity will be better seen by a consideration of daily observations, which will be dealt with later.

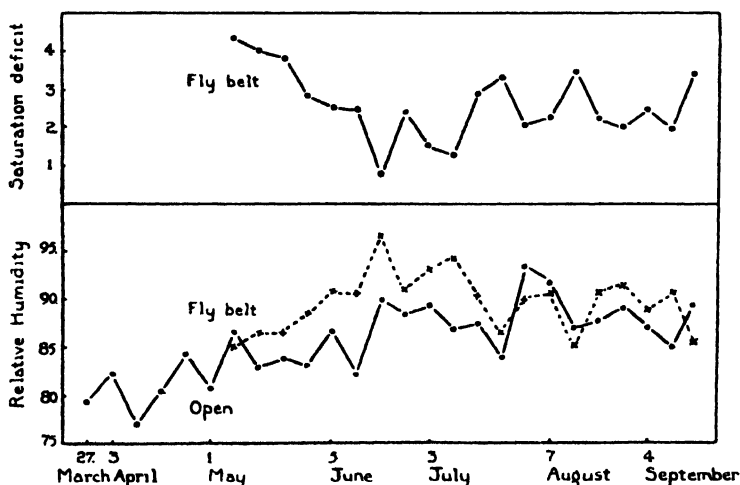


Fig. 5. Average daily relative humidity of the open, taken by a stationary wet and dry bulb hygrometer, and relative humidity and saturation deficit of the fly belt as taken by a whirling hygrometer. Takoradi, 1931.

In attempting to demonstrate the relative significance to the fly of the different climatic factors, the statistical method of calculating correlation coefficients will be helpful. The formula used for finding the simple linear correlation between pairs of variables is as follows :—

$$r = \frac{\text{mean } xy - (\text{mean } x \times \text{mean } y)}{\sigma x \times \sigma y}$$

where r is the coefficient of correlation, x and y are the variates, and σx and σy the standard deviations of x and y . A correlation coefficient may fall anywhere between +1 and -1, and unity is perfect correlation, 0 indicating no correlation. In positive

correlations one variate increases with the other, in negative correlations as one increases the other decreases. If the correlation is greater than three times the probable error, it is considered as significant, *i.e.*, greater than might be obtained by laws of chance. By this method the following correlations were determined; either direct, a week's fly figures correlated with the same week's climate, or with a lag, the fly figures correlated with the previous week's climate. As the week's lag was in every case less than the direct correlation, and from a consideration of the graphs, lags of more than a week were not determined as likely to be of even less value. The number of observations on which the correlations were based was in the case of temperature, saturation deficit, and atmometer, twenty; and in the case of sunshine, rainfall, and the relative humidity of the screen, twenty-six.

TABLE II.

Coefficients of Correlation of Tsetse Density—activity with Climate, March to September, 1931.

Correlation	Direct	Probable error	1 week's lag	Probable error
Fly with temperature ... ..	.760	±.064	.578	±.100
Fly with saturation deficit ...	.504	±.112	.213	±.144
Fly with atmometer ... ..	.408	±.126	.277	±.139
Fly with sunshine ... ..	.489	±.115	.1723	±.146
Fly with rainfall ... ..	.194	±.145		
Fly with relative humidity of screen	-.424	±.108		

There is a high positive correlation between fly and the temperature of the same week, slightly lower for the previous week's temperature. That between fly and saturation deficit is fairly high for the same week, but ceases to be significant with a week's lag. Similarly both atmometer and sunshine show a significant direct correlation, but lose this significance with a week's lag. There is no significance in the correlation between fly and rainfall. In the case of the relative humidity of screen, *i.e.*, taken with a stationary wet and dry bulb hygrometer in a Stevenson screen, the correlation is negative and significant. This bears out what has been said above on the validity of using standard meteorological data on humidity in climatographical work on this species of tsetse.

By the method of partial multiple correlations, it is possible to bring out more clearly the relative importance of the different factors. This is done by eliminating, mathematically, one factor, say evaporation, and determining what the correlation would be between fly and another factor, say temperature, were evaporation held constant. The formula employed in this case is:—

$$r_{xy.z} = \frac{r_{xy} - r_{xz} \cdot r_{yz}}{\sqrt{(1 - r_{xz}^2)(1 - r_{yz}^2)}}$$

where $r_{xy.z}$ is the coefficient of correlation between two variates x and y , when a third variate z is constant, r_{xy} , r_{xz} , and r_{yz} are the coefficients of correlation between x and y , x and z , and y and z respectively. In this way the correlations shown in Table III were determined.

These figures show, in a most striking way, the major influence of temperature on the fly's density-activity during the period of observations. They also show how atmometer evaporation effects its main influence through temperature, whose correlation coefficient is hardly affected by the elimination of atmometer, which, however, is itself rendered quite insignificant by the elimination of temperature. Similarly, sunlight must have its main influence through temperature, but saturation deficit seems to be the most independent of temperature, the elimination of this factor making the greatest difference to the temperature coefficient, although saturation deficit by itself, with temperature held constant, loses its significance.

TABLE III.
Partial Correlations of the Data analysed in Table I.

Partial correlation between	Direct	Probable error
Fly and temperature, with saturation deficit constant ...	·659	± ·087
Fly and saturation deficit, with temperature constant ...	·004	
Fly and temperature, with atmometer constant	·702	± ·078
Fly and atmometer, with temperature constant	·045	
Fly and temperature, with sun constant	·680	± ·083
Fly and sun, with temperature constant	·032	

All these correlations are linear, or straight line correlations, and it is recognised that the closest correlation between the fly and climate is curved or skew. The number of observations was not sufficiently large, however, for a skew correlation to be worked out in the present case. The results of this mathematical analysis, showing the high significance of temperature and the comparatively small influence of evaporation and humidity on the fly's density-activity, seem, at first sight, to be rather at variance with both personal observation and general conclusions on the importance of humidity to tsetse. The explanation of this is based upon the fact that an insect's reactions to a climatic factor are less intense when the factor is near the optimum for that insect, and increase in intensity as the limit of toleration is approached. It is probable, then, that during the period of observations, the range of humidities in the fly-belt was so uniform and well within the tsetse's range of toleration that its variations had little effect upon the fly. The range of temperatures, on the other hand, was further from the optimum and approaching the limit significant for the fly's activity, and therefore of far greater effect. This is borne out by further observations.

Another important point emerges from this mathematical analysis. In every case the correlation is greatest when made direct, the fly catches with the climate of the same week, indeed temperature is the only factor that shows a significant correlation coefficient with a week's lag. The inference is that it is the activity of the fly more than its density which is being affected in this way by these factors, and a further attempt will be made to discriminate between the climatic effects upon activity from those of density. Immediate effects, relating to activity, can better be studied from the day-to-day figures of fly-catches and climate. For this purpose it will be sufficient to quote the figures for April, a dry month, and June, a wet month. The graphs of fly-catches, hours of sunshine and rainfall for April are given in Fig. 6. It is not worth complicating the figure by the inclusion of the curves for temperature and

humidity, as their effect is not so marked in day-to-day observations, and has been already demonstrated in the consideration of weekly averages. It is noticeable that during April the peaks in tsetse activity are on days of little or no sunshine, the correlation with sunshine being evidently negative. Rainfall is certainly accompanied

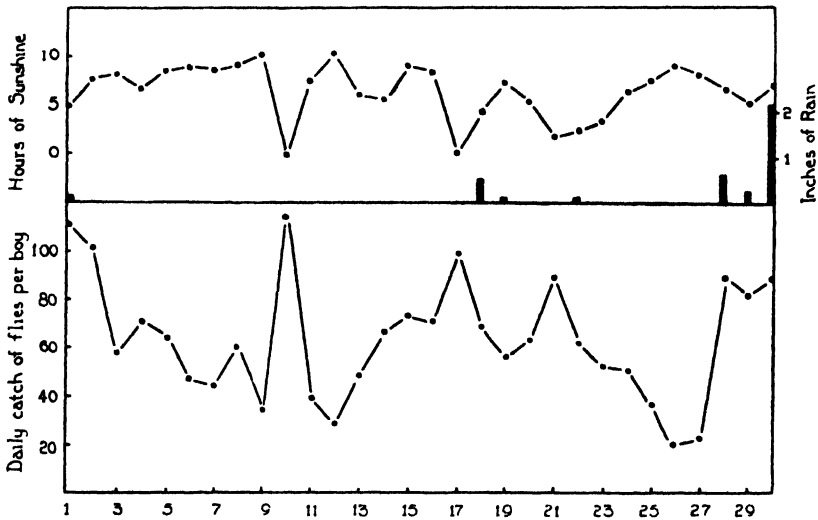


Fig. 6. Fly density-activity, sunshine and rainfall in area B during April 1931.

by activity. The correlation with saturation deficit was also negative; there was a very low deficit, 4 mm. or less, on the days of maximum fly-catches. This type of reaction did not last long. In May there was a considerable rainfall and sunny days were less frequent, and by June the effects seemed to be reversed, as will be seen from Fig. 7. Now dull days and heavy rainfall are accompanied by a considerable drop in

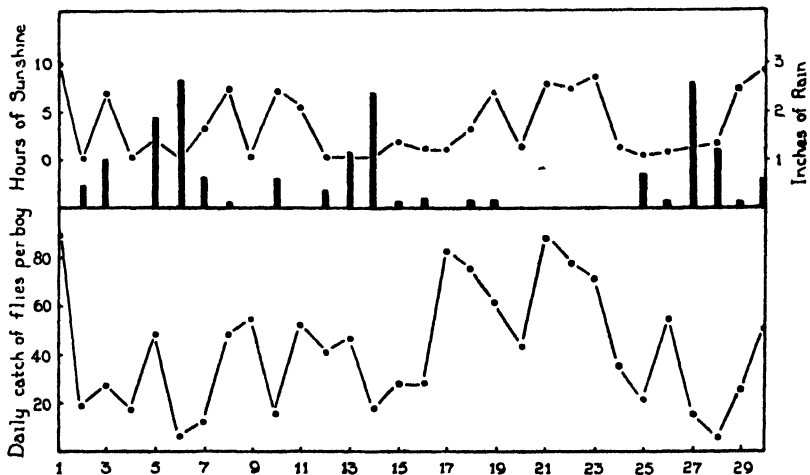


Fig. 7. Fly density-activity, sunshine and rainfall in area B during June 1931.

fly numbers, the effect persisting for a day or two after the rain. The highest catches were made on the first of the month, which followed a dry end of May, and during the dry and comparatively sunny period between the 15th and 24th. Saturation deficit was now mainly low, averaging 2 mm., and rose above 4 mm. only on the 1st of the

month, on the 7th, 8th and 9th, and between the 17th and 21st. There is now a positive relation with saturation deficit and sunshine, and negative with rainfall. Such a change in the nature of these correlations supports the assumption that the closest correlation between fly and climate is curved or skew, being negative over a part of the range and positive over the other part. This inhibiting effect on the fly's activity was very noticeable when catching tsetse in the bush. A heavy shower in the middle of a bright sunny day would cause an immediate disappearance of tsetse, half-drowned inactive flies would be seen clinging to the undersides of leaves, making an attempt to escape. The passing of the shower and an hour or two's sunshine and warmth would bring the flies once more to active life.

A study of the hourly activity of the fly throughout the day gives interesting information. During the seven months of observation, hourly catches were always recorded, and during one week in August and 18 days in September, hourly catches were correlated with readings of shade temperature and relative humidity, taken with a whirling hygrometer. During the night this species of tsetse was normally inactive. Flies have certainly been caught on occasions round lamps after dark, but this is exceptional. After sunrise, during the first hour or two of daylight, tsetse were invariably quiescent, none would be seen until suddenly about 8 or 9 a.m. large numbers would appear, and shortly after this time the maximum catch for the day would be made. Gradually the numbers would fall off until a definite lull in fly

TABLE IV.

The Hour of Maximum Activity of G. longipalpis in the Fly-belt, and Monthly Means of Shade Temperature and Humidity taken at 9 a.m. in Fly-belt.

	March	April	May	June	July	August	Sept.
Hour of maximum activity	8-9	8-9	9-10	10-11	10-11	10-11	9-10
9 a.m. fly-belt temperature, °F.	86	84.7	81.3	78.3	76.7	76.0	77.3
9 a.m. fly-belt saturation deficiency, mm.	5.2	4.8	2.9	1.4	2.1	2.5	2.6
9 a.m. fly-belt relative humidity, per cent.	83.3	84.9	88.4	93.4	90.8	88.4	88.6

activity occurred soon after midday, as few as 3 to 6 flies an hour being caught at this time, when 15 or 30 had been taken at the hour of maximum activity. There was always a slight resumption of activity in the afternoon, but after 4 p.m. the numbers fell off rapidly, and at sundown none would be caught. Fig. 8 is based on an average of 15 days' hourly observations in September, and represents typically the diurnal activity of this tsetse. From month to month the curve of activity remained essentially the same, with approximately a four-hour interval between the maximum and minimum activity periods, but the whole of this cycle of activity occurred an hour earlier during the dry and warm months, and an hour later during the colder and wetter months, as can be seen from Table IV.

Thus pushing back of the hour of maximum activity of the fly during the wet and cold months seems to furnish a key to the question of the toleration of climatic factors by the fly, but it is necessary first to determine how much its daily rhythm is dependent on climate, or is biological or intrinsic to the insect itself. The first sudden activity of the fly is certainly due to hunger, the percentage of females in the catch being always greatest at this time, and the flies were generally more active and more ready to feed upon the catchers in the early morning. The midday drop in activity is probably associated with tiredness or with digestion on the part of those flies that have fed in the early morning, though this cannot be demonstrated, only negative evidence of the lack of correlation with climate is available.

A study of Fig. 8 certainly gives the impression that the midday inactivity is correlated with maximum temperature and saturation deficit, but this does not hold good for the other months. In August, for example, the maximum temperature of 81°F. and maximum saturation deficit of 5.5 mm. was at 12 noon, but the minimum fly activity fell between 3 and 4 p.m. At this time, 4 p.m., both temperature and saturation deficit were of the same value as at 10 a.m., the hour of maximum fly activity. Again, the range of daily maxima for these two climatic factors varied so greatly, between 75 and 84°F. temperature, and between 4.7 and 8 mm. saturation

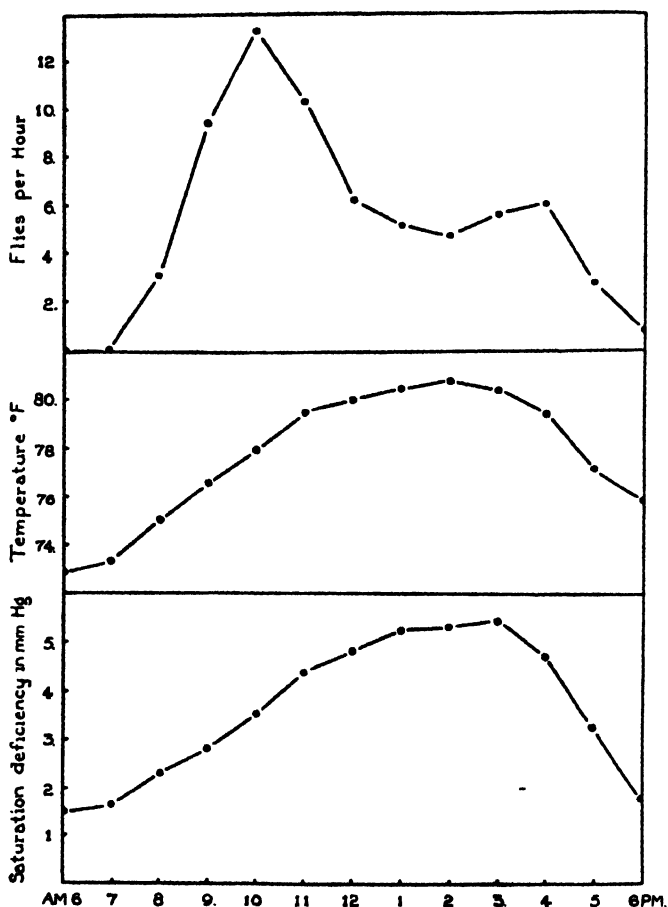


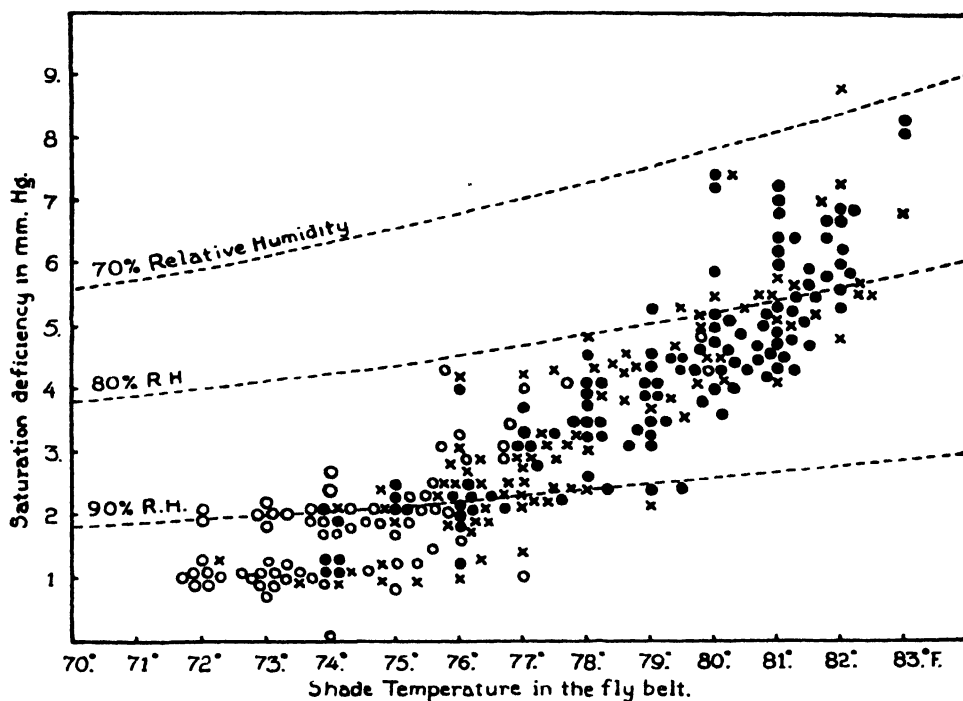
Fig. 8. Average hourly activity of *G. longipalpis*, temperature and saturation deficit in fly-belt B, for period 1st to 18th September, 1931.

deficit, that these cannot be considered as having the regularly adverse effect necessary to bring about the constant drop in fly activity. This middle day quiescence must, then, be a part of an intrinsic rhythm in the fly, and not due to climatic factors. Similarly, the slight resumption of activity in the afternoon has been found to show no correlation with temperature or humidity and, from observations in the field, is probably a second hunger reaction. These two feeding periods of the fly perhaps bear some relation to the morning and evening periods of activity of the game animals that form its natural food, and, if this is true, it emphasises the significance of the fact

that the fly is entirely inactive during the early morning hours, when game is most active and easy to find. Here, it seems, climatic factors do play a major part in controlling the flies' activity, and this can be demonstrated in several ways.

Firstly, there is the variation in the hour of maximum activity, as has been illustrated in Table IV. The combination of low morning temperatures with very low saturation deficits in June, July and August affords the most likely explanation of the lateness of the flies' activity in those three months.

Secondly, as has been pointed out before, a period of low temperature and high humidity accompanying a shower during the day will entirely inhibit the tsetse's activity. As an illustration, two days in September may be cited, since we have for comparison the average temperature, saturation deficit, and fly activity for the greater part of that month (fig. 8). On 8th September, the maximum catch of 14



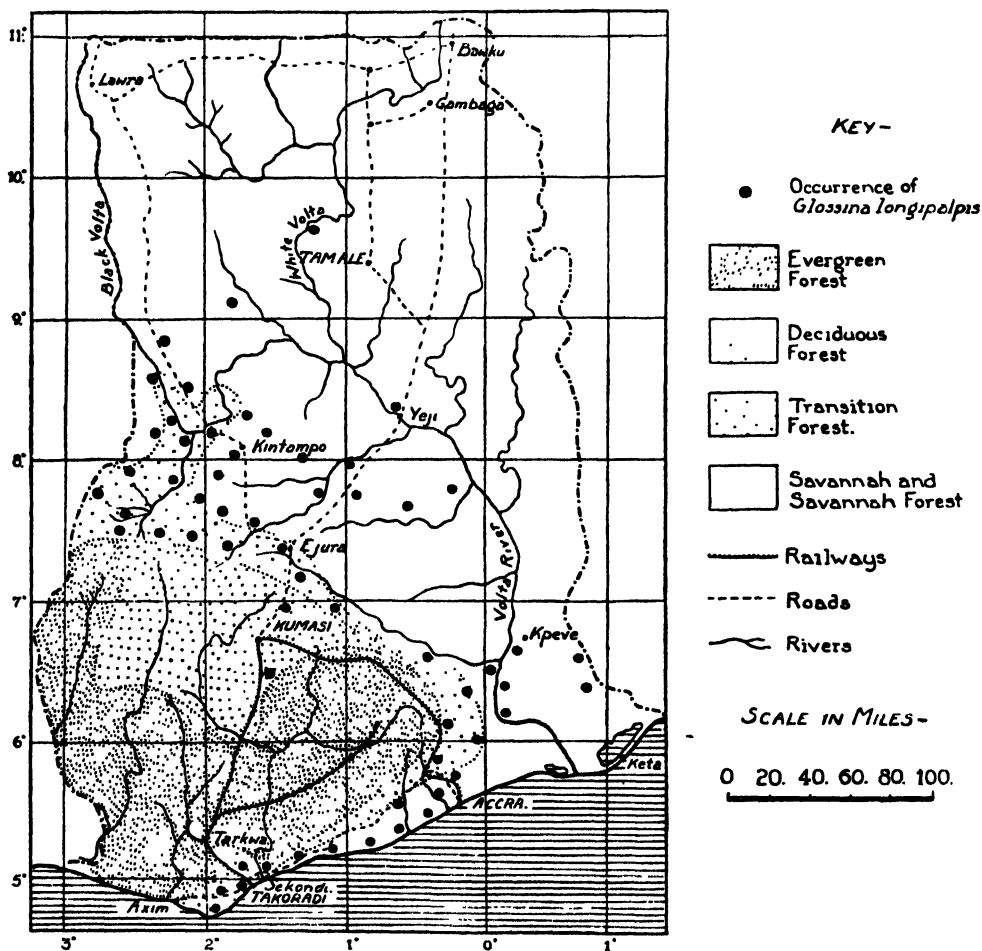
○ = No flies per hour. x = 5 or less flies per hour. ● = Over 5 flies per hour.

Fig. 9. The activity of *G. longipalpis* in relation to temperature and humidity.

flies an hour was made at 10 a.m., and by 12 noon the catch was 8 flies an hour. Between 12 and 1 there was a heavy rain storm, saturation deficit dropped from 4.2 mm. to 1.6 mm., and temperature from 80°F. to 75.5°F., and no flies were caught during that hour. Between 2 and 3 p.m. the sun was shining, saturation deficit had risen to 3.3 mm. and temperature to 78°F. and the catch was 7 flies an hour. On 17th September, the maximum catch of 19 flies was made at 9 a.m.; at 10 a.m. there was fairly heavy rain, and only 7 flies were caught, saturation deficit having dropped from 3.3 to 0 mm., and temperature from 79°F. to 74°F. By 12 noon the day had cleared, and saturation deficit was 3.5 mm. and temperature 79°F., and 16 flies were caught.

Finally, the information from those hourly observations in August and September can be further analysed. From Fig. 8 it can be seen that the temperature

prevailing during the hours of activity is below 74°F., the saturation deficit is below 2 mm. The significance of these factors can be brought out more fully by plotting the individual hourly catches of tsetse for the whole period of 24 days against temperature as ordinate and saturation deficit as abscissa (fig. 9). For this purpose the fly catches were divided into three groups; one, no flies caught; two, catches of five or less tsetse; three, catches of over 5 tsetse. Admittedly, the latter division is entirely arbitrary, but some attempt had been made to distinguish small catches, indicating flies present but inactive, from large catches, indicating flies fairly abundant and active. The maximum number of flies caught in an hour was 30, the average maximum catch was 14, so catches of 5 or less did represent considerable inactivity and



Map 2. The Gold Coast. Distribution of *Glossina longipalpis* and of Forests.

scarcity of the fly. The figure so obtained is, admittedly, limited, the range of temperatures and humidities is too small, but it does, at any rate, show very definitely the lower limits of these two factors at which activity takes place. Temperature is the most clearly defined. Below 74°F. only two small catches of tsetse were made, and this is evidently the limit for activity. There is no such clearly defined limit for the humidity factor. Below 2 mm. saturation deficit (90 per cent. relative humidity at prevailing temperature), the majority of observations show no tsetse or only small

catches, but even at 1 mm. saturation deficiency large catches were made. Apparently such high humidities can be tolerated, especially at higher temperatures, but are not conducive to activity. At lower humidities and higher temperatures the number of zero and small catches decreases and the proportion of large catches increases until the limit of the range of observations is reached. Another point brought out by this figure is the fact that there is not a great deal of difference between the distribution of small catches and large catches, which implies that there is a sudden awakening into activity above the critical temperature and saturation deficit, also that activity may be low even with favourable climatic conditions. This supports what has already been said about the daily rhythm in the fly's activity, which, apart from the early morning inhibition, is independent of temperature or humidity.

The results of this study of climatic influence upon *G. longipalpis* is to demonstrate a high positive correlation of fly activity with temperature and a lower correlation with humidity, of which saturation deficit is a better index than atmometer evaporation. This correlation with humidity is effective mainly through temperature, and the phenomenon that temperature is of major influence on the fly's activity, and humidity of very minor influence, is due to the fact that the temperature range is close to the lowest point significant for the fly's activity, whereas the humidity range is more tolerable to the fly.

There still remains a further and valuable means of elucidating the influence of climate upon this species of tsetse; this is by a study of the fly's distribution. Map 2 depicts the distribution of *G. longipalpis* in the Gold Coast, and also the main forest areas, as described by Chipp (1922, p. 12). The distribution of the tsetse is compiled partly from the writer's experience, and also from a number of reliable sources, the chief of which are Simpson (1914), Young (1925), Kinghorn (1911), Ingram (1914), Macfie (1923), and Fell (1912).

From a glance at the map it will be seen that this species occurs mainly in the belt of Transition Forest that surrounds the Deciduous and Evergreen Forest, intermediate in character between this and Savannah. It is significant that the only two occurrences of this fly within the true forest are on a main road and on the railway, and it is certain that in its normal distribution it never occurs within the forest. It does, however, occur in Savannah country in a number of places, notably along the sea-coast, round the Volta basin, in the neighbourhood of Kpeve, all around Kintampo, and to the south of Yeji. The occurrences on the Volta at Yeji and west of Tamale are exceptional, and based on isolated catches in each case.

Can this distribution be due to any other factor than climate? Food can certainly not be held responsible, as the small antelopes that form the fly's main food at Takoradi are distributed widely throughout the forest and are replaced by other species in great abundance in the open savannah to the north. Vegetation alone cannot account for it, unless we take into account the ecoclimate of the different vegetational types, and here, indeed, seems to be the key to the whole problem. Climatographs of three main areas have been drawn, using figures from "*A Summary of Climate according to Zones of Vegetation*," drawn up by Chipp (1922, p. 37) from 15 years' data at 13 different stations on the Gold Coast. These diagrams, of Deciduous Forest, Coastal Savannah, and Inland Savannah, are given in Fig. 10. Evergreen Forest is not included, as its climate is so very similar to that of Deciduous Forest. No climatograph of Transitional Forest has been drawn, because very little data from stations in this area are available, but from a comparison of yearly meteorological statistics, it approaches very closely the climate of Coastal Savannah, with the same temperature range, but a larger range of humidities.

First, to consider the climatographs of these three main vegetational types, it is evident that temperature can play no part in the exclusion of the fly from forest or

savannah, but humidity is the decisive factor. Relative humidity in the forest never falls below 80 per cent., whereas in savannah it is never above 80 per cent. Coastal Savannah, because of the constant moisture-laden sea-breezes, shows a very narrow range of humidities, between 75 and 80 per cent., whereas Inland Savannah is subject to very low humidities in the winter months, due to the dry Harmattan wind, which blows in the north from December to February. Here then, must lie the explanation of the fly's distribution; the constantly high humidities of the forest are intolerable to it, equally so are the low humidities prevailing in Inland Savannah during the dry

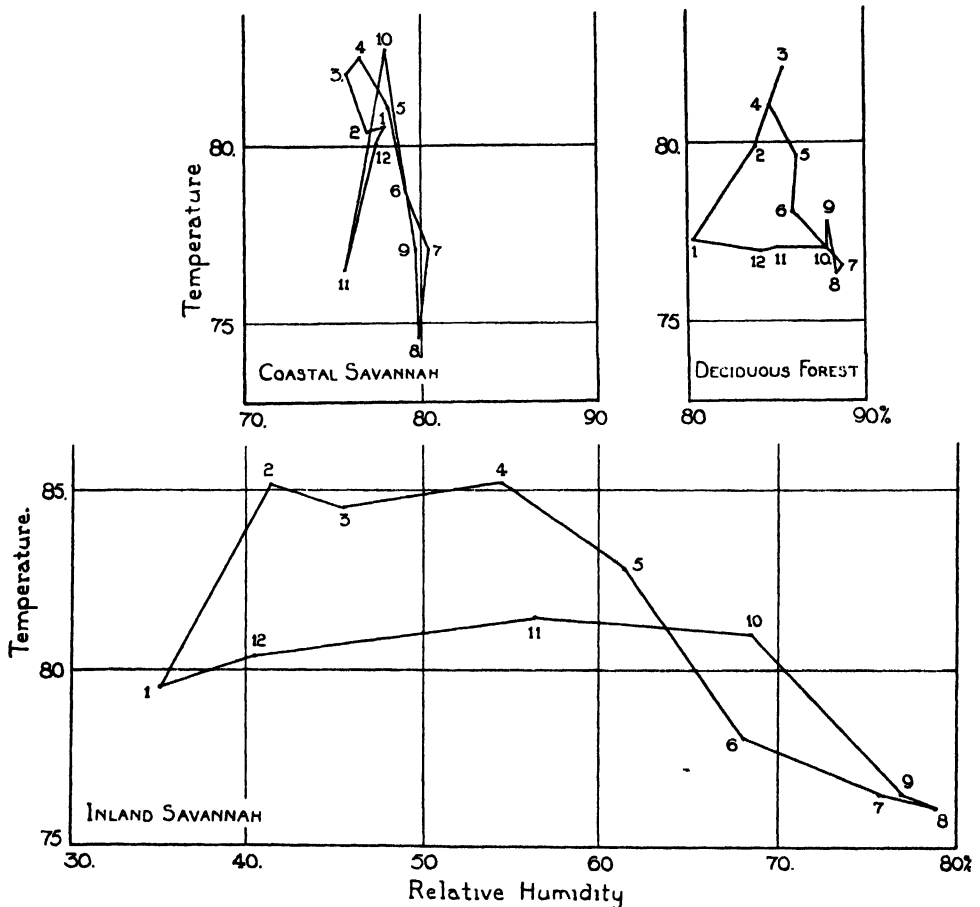


Fig. 10. Climatographs of Deciduous Forest, Coastal and Inland Savannah.

season. But it can be seen from the map of distribution that this species does occur in Inland Savannah, notably around Kintampo, to the south of Yeji, and in the neighbourhood of Kpeve. The explanation is to be found in the distribution of rainfall in the Gold Coast. Kintampo itself is the centre of an area of very heavy rainfall, 70 to 75 inches yearly, and the other localities where this tsetse occurs in savannah, those to the north of Kintampo, south of Yeji, and around Kpeve, all lie within the area having a rainfall of over 55 inches yearly, which is a higher precipitation than occurs either along the coast or in the northern and eastern parts of Inland

Savannah. That this raises the air humidity of these areas can be shown by climatographs of Kintampo and Kpeve drawn from data for the year 1929, which was neither an abnormally wet nor abnormally dry year (fig. 11).

To summarise, then, *G. longipalpis* occurs in three distinct types of vegetation in the Gold Coast; the thick secondary bush of the Transition Forest extending all round the periphery of the Rain Forest and including Takoradi; the Coastal Savannah Forest extending from Sekondi eastwards, consisting of a great deal of thick secondary

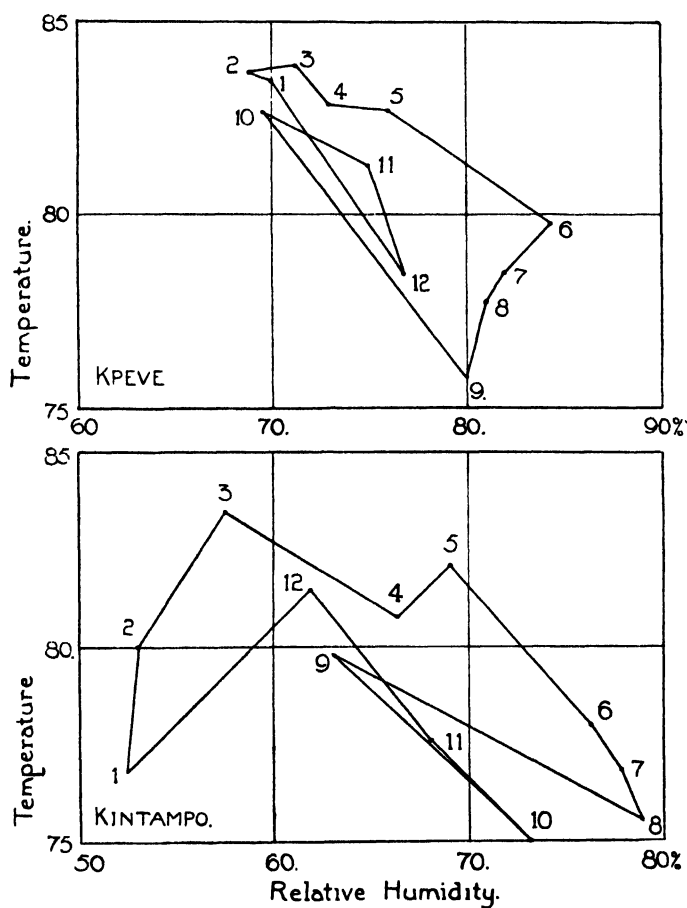


Fig. 11. Climatographs of Kintampo and Kpeve.

bush, but with abundant open spaces; and the Inland Savannah Forest round Kintampo, Yeji, and Kpeve of an open woodland type. All of these have a similar ecoclimate, which is not reproduced in the Rain Forest or northern Savannah, the difference between fly-belt and fly-free country lying in humidity and not in temperature. The range of the fly-belt is, very roughly, between 50 and 60 per cent. relative humidity, and between 75°F. and 85°F. in temperature, from standard meteorological observations. The conclusion is that, given the presence of game animals for food, the distribution of *G. longipalpis* in the Gold Coast is mainly dependent upon humidity.

7. Infection with Trypanosomes.

During April and May 1931, the trypanosome infection of *G. longipalpis* was studied by Lloyd & Johnson's method of dissecting and examining proboscis, salivary glands, and mid-gut of the fly (Lloyd & Johnson, 1923). The majority of flies came from Area A, but a number were examined from bush to the north and west of Takoradi, and no difference in infection was found. In April the commonest species of trypanosome found was of the *Trypanosoma congolense* group, occurring in 24 per cent. out of 200 flies examined, very massive infections of crythridial and infective forms being found in the labrum and hypopharynx. Five per cent. of the flies were infected with *T. vivax* group trypanosomes. In May and June just under 300 flies were examined and the number of *T. congolense* infections was 20 per cent., of *T. vivax* 4 per cent., and one (or 0.3 per cent.) infection of the salivary glands with the polymorphic group trypanosome was found. Experiments were then undertaken of feeding wild infected flies on guinea-pigs and rats, in an attempt to infect them with these trypanosomes. Six clean guineapigs and six clean rats had flies infected with either *T. congolense* or *T. vivax* fed upon them, and three guineapigs and one rat were injected with teased-up proboscis of infected flies. These experiments and their results have already been published (Morris, 1932) and it is sufficient to say here that one guinea-pig became infected from the feeding of a fly, the infection proving to be a mixture of *T. congolense* and *T. gambiense*. The identity of the trypanosomes was confirmed by Dr. Saunders, Pathologist of the Medical Research Institute in Accra. This is sufficient proof that *G. longipalpis* can act as vector of the trypanosomes pathogenic to man and to domestic animals.

Although sleeping sickness cases have been very rarely recorded at Takoradi up to this date, the source from which the fly became infected with *T. gambiense* must have been human. A fair number of Northern Territory boys were working in and around Takoradi, building, farming, etc., and some of these boys might have introduced the disease either from the Northern Territories or from Ashanti. The game animals of this area undoubtedly acted as reservoirs for *T. vivax* and *T. congolense*. A bushbuck and two black duikers were examined and found, in the first case, to have a mixed infection of *T. vivax* and *T. congolense* in the blood, and of the two latter one was infected with *T. congolense*. There is no domestic stock at Takoradi that might harbour these trypanosomes; small numbers of sheep, goats, and pigs are kept in outlying villages, but examinations of a proportion of the animals at Amanfull, a small village 3 miles west of Takoradi, showed no infections. Cattle that have been driven down from the north or imported by sea are brought to Takoradi slaughterhouses regularly, and such cattle usually show an extremely high percentage, 90 per cent. or more, of trypanosomes of the *T. congolense* and *T. vivax* groups. Thus there is a continuous introduction of infection with these trypanosomes, right into Takoradi itself.

8. Conclusions on the Control of *G. longipalpis* in the Gold Coast.

The importance of *G. longipalpis* as a vector of trypanosomes in the Gold Coast must first be considered. In the distribution of sleeping sickness it is probably second in importance to *G. palpalis*. It is, in general, more important than *G. tachinoides*, whose contact with humans is limited to the upper Volta basin and the drier areas of the Northern Territories, where, however, the human population is not great. It is certainly more important than *G. morsitans* whose continually receding population is now limited to the remoter bush in the central and western parts of the Northern Territories. In those districts of the Gold Coast where sleeping sickness has for long been known to be prevalent, the north-western parts of Ashanti, especially round Kintampo and Fenshi, this species is, in places, as common as or even more common than *G. palpalis*, and from its more homogeneous distribution (by which is implied its wider ranging powers in the wet season, as well as its not being confined

strictly to water-courses), it is more likely to come into contact with an agricultural community. This is offset to a large extent by the observations that *G. palpalis* seems to favour a human diet, whereas *G. longipalpis* does not, at least so far as the detailed observations at Takoradi show. It is quite possible that in the Ashanti districts, where this fly has a longer and more intimate contact with man, it is taking more readily to human food. Be that as it may, this fly does, undoubtedly, play a large part as a disseminator of sleeping sickness in the Gold Coast.

In the case of animal trypanosomiasis it is probably not as important as *G. tachinoides*, which is the prevalent species in the major cattle-breeding districts of the Gold Coast, with the exception of the Accra plains, where *G. palpalis* alone is found. On the more southern parts of the routes by which cattle are driven into the country from French Haute Volta territory, and as a menace to horses and to non-immune domestic stock, it plays an important rôle.

The future, if one may discuss a tsetse fly's future, merits special attention. The distribution of *G. longipalpis* in Savannah Forest of a moist enough climate, and especially in the Transition Forest between Savannah and Rain Forest, has been described. Now there is strong evidence (Chipp, 1922, pp. 3-6) to show that over a large part of West Africa savannah is gradually encroaching on forest. This is brought about, in the first place, largely by the natives themselves; by their shifting system of agriculture, where farms are deserted after two or three years, and by their tendency to desert their villages for trivial reasons, such as the death of a chief or the onset of sickness; or, in one case which came under the writer's notice, because a signpost pointing to that village had been placed on a main road near by! The bush that recolonises these deserted farms and villages is of a secondary type, essentially suitable for the occupation of *G. longipalpis*. Forest seldom or never becomes established again, partly because of the desiccating effect of the Harmattan wind and the fierce grass fires in winter. The rainfall of Kintampo and Ejura is identical with that of Evergreen Forest, and there are strong floristic affinities between the forest and patches of fringing forest remaining around these districts; so it seems reasonable to assume that true Rain Forest once extended at least as far as these towns. In the Gold Coast the forest is receding from both the north and the south. This steady retreat of the forest, then, will render more and more land available for colonisation by *G. longipalpis*. At the same time as civilisation advances, this species will not retreat, as does the other game-feeder, *G. morsitans*, but will remain in suitable habitats so long as there is a sufficiency of food, in the form of small game animals. The case of Takoradi is sufficient proof of this. There will be, moreover, the ever-present danger of the fly's taking more readily to the human source of food.

In recommending control measures against *G. longipalpis* in the Gold Coast, simplicity and generality of application are the aims that will be borne in mind, remembering always the varied vegetational character of the fly-belts occupied by this species. For this reason, several possible methods may be summarily dismissed. Hand-catching, for example, though it effected a marked reduction in tsetse in section A at Takoradi, and showed promise of eventually reducing the fly to really small numbers, is applicable only to such small, isolated fly-belts as there described. It is too much to suppose that in uninterrupted fly-belts this would be a success.

Experiments in trapping adults with a simple screen tray were started on a small scale in May and June; the results were so small as not to be worth setting out in detail, but it was obvious that in this dense vegetation of Transition Forest traps are useless.* It is possible that they might be more effective in Savannah, but in

*[The trapping of tsetse-flies requires special knowledge and experience, without which the results of casual trapping experiments may be quite misleading. In East Africa *G. pallidipes* (which is the local representative of the western *G. longipalpis*) has been shown to be specially amenable to trapping, if the right type of trap is used, and it is probable that this will apply also to *G. longipalpis*.—Ed.]

the absence of definite proof of the control effected by traps when working at their best, other lines must be followed.

Bush-clearing, with the object of eliminating primary foci of the fly, is out of the question under the present economic conditions. In this type of homogeneous distribution of tsetse over large areas of dense bush, the amount of clearing necessary to eradicate all breeding-places would be colossal. Furthermore, because of the high humidities prevalent in fly-belts of this species, regrowth on the cleared land will be extremely rapid and the cost of maintenance of the clearing, in consequence, excessive. There is that type of clearing which may be termed "exclusive clearing," aiming at the exclusion of tsetse from a definite object, a road, village, or ferry, without attempting the removal of the primary foci by what may be called, in distinction, "eliminative clearing." This "exclusive clearing" has already been carried out with measurable success against *G. palpalis* and *G. tachinoides* in the Gold Coast (Pomeroy & Morris, 1932). The execution of such clearings round places of importance must be the first step in any campaign against *G. longipalpis*. Because of the generally high humidities prevailing during most of the year in country infested by this species, especially in the Coastal Savannah, and because of its tendency to extend its range during the rainy season, clearings must be considerably more extensive than those necessary for the exclusion of *G. palpalis* or *G. tachinoides*. It is difficult to enunciate a standard distance for general application; this depends on the nature of the fly-belt, the position and importance of the town, etc. A clearing aiming at an absolute exclusion of tsetse would be ideal, but probably excessively great for "effective" exclusion, and therefore uneconomic. "Effective" exclusion must be considered as the exclusion of tsetse up to that point in density below which the chances of its transmitting trypanosomiasis are negligible. We have no evidence as to what degree of density of tsetse this might be, though it might be approximated by a careful comparison of tsetse counts with the incidence of trypanosomiasis. As a working basis for clearing bush villages, 100 yards should be the minimum distance to be cleared all round the village. For larger and more important towns this distance should, at least, be doubled. The question of clearing roads is even more difficult. As 40 or 50 yards width of clearing on each side of a road would be necessary to produce even partial protection from the fly, and in most of the country infested by this species, roads pass for considerable distances through fly-belts, a tremendous lot of clearing would be involved and would probably not be worth while. It is important, however, to stress the folly of small clearings, 30 to 50 yards across. These, in effect, reproduce the natural feeding-grounds of the fly found in valleys in the bush, and are therefore more likely to prove a curse than a blessing.

It is of the utmost importance that clearings once undertaken should be maintained, and farming is almost invariably the best way of accomplishing this. One of the most impressive observations made at Takoradi was on the immediate effect extensive farming and wood-cutting has in excluding *G. longipalpis* through driving out the small antelope. Section C was by no means the only place where this was occurring; it had taken place, or was in the process of taking place, at a number of spots round the new and old native towns, and along the road and railway where the natives were allowed to farm, and it would most certainly be possible, by encouraging farming in sections A and B, to eliminate tsetse eventually from these fly-belts.

At the same time, the danger has already been pointed out of odd farms being scattered here and there throughout the bush, and often remote from the village. Such a system of agriculture is pernicious in three ways. Firstly, to reach their farms the natives have to traverse a greater or less extent of fly-belt. Secondly, when the farm is planted and growing, it is not frequently visited, and so attracts game and becomes a feeding-ground for *G. longipalpis*, so that when the crop is harvested the natives will be exposed to the fly. Thirdly, when the farm is abandoned the subsequent regrowth of vegetation is particularly suitable for colonisation by the fly.

An improved system of native farming, then, should be the basis of all attempts to control this species of tsetse in the Gold Coast. As development proceeds, farming should be encouraged and carefully organised. The farms should be kept in proximity to one another and as close to the villages as the nature of the soil will permit. Above all, continuous farming on the same ground should be aimed at. Groundnut is almost the only crop that can be raised on the same land for many successive years, and as the staple diet in Ashanti and the Gold Coast is cassava, some sort of rotation of crops must be attempted, as well as manuring of the ground.

9. Summary.

A detailed study of the bionomics of *Glossina longipalpis*, Wied., was undertaken at Takoradi, the principal port of the Gold Coast in West Africa, and lasted from February to September 1931.

The topography of this country is undulating; the vegetation is of Transition Forest type, intermediate in character between Rain Forest and Savannah Forest, and of an exceedingly dense, homogeneous nature, with a few small glades in the forest, and interrupted by large open marshes on the lower and flatter ground.

The climate is remarkably equable, with a low mean annual rainfall between 40 and 45 inches, but constantly high humidities, owing to the moisture-laden sea-winds. There is a double rainy season, the main rains from April to July, and a second shorter period of rainfall in October and November.

There is a rich mammalian fauna, with the exception of the larger game animals.

Three species of *Glossina* occur: *G. longipalpis*, Wied., the commonest, evenly distributed throughout the bush, and the only species dealt with in this paper; *G. palpalis*, R.-D., confined to water-courses and the edges of lagoons; and *G. medicorum*, Aust., rarely met with.

Two isolated fly-belts, identical in every way, were studied. In one, section A, flies were caught and killed daily; in the other, section B, the control area, the flies were liberated after noting the catches. By September, the tsetse population of A had been reduced to less than one-third of that of B, presumably the effects of catching and killing.

The main food hosts of this species were the bushbuck and duiker, ubiquitous in this forest. When these small game animals were driven out of a third fly-belt, section C, by farming and wood-cutting, the fly quickly and completely disappeared. This species was never found to feed on reptiles, although they were common in the fly-belts.

Meteorological observations in the open country and in the fly-belts showed a consistently lower temperature and higher humidity in the latter, as well as its greater equity in these factors. The movement of the fly into the open was apparently governed by humidity, the greatest movement taking place when the humidity of the open was within the normal range of fly-belt humidity.

By statistical methods, coefficients of correlation were determined for the fly's density-activity and various climatic factors of the fly-belt. The fly showed a high positive correlation with temperature, and a lower correlation with humidity, of which saturation deficit was a better index than atmometer evaporation. There was a significant correlation with sunshine, but none with rainfall. This correlation with humidity was mainly a temperature effect, as was also the correlation with sunshine. Temperature was evidently of major importance. There was a significant negative correlation between fly and relative humidity, measured with a wet and dry bulb hygrometer in a screen in the open.

All correlations were greatest when considered direct, the fly catches with simultaneous climatic readings, indicating that these factors influence the activity of the

fly in this way, rather than its density. The fly was found to be inactive at temperatures below 74°F., with high humidities of 80 or 90 per cent. or over. This explains the major influence of temperature, shown by the methods of correlations. The temperature range in the fly-belt, during the period of observations, was close to the temperature significant for the fly's activity, and therefore variations produced marked reactions; the humidity range was much closer to the fly's optimum and therefore better tolerated.

There is marked daily rhythm in the fly's activity, which is only influenced by climate under extremely unfavourable conditions of temperature or humidity.

The distribution of *G. longipalpis* in the Gold Coast is dependent upon the humidity of the ecoclimate, rather than upon temperature. It occurs in three main vegetational types—Transition Forest, Inland Savannah Forest, and Coastal Savannah—where the range of humidities is between 50 and 80 per cent. R.H., and temperature between 75° and 85°F. It does not occur in the Rain Forest, where the relative humidity is constantly above 80 per cent., or in northern Savannah, where the humidity is as low as 30 per cent. in the dry season.

The main breeding season was from March to July with its maximum in May, at the height of the rains.

This species was found infected with *Trypanosoma gambiense*, *T. congolense*, and *T. vivax* at Takoradi, and is probably second in importance to *G. palpalis* as a vector of sleeping sickness in the Gold Coast, but at present of less importance than *G. palpalis* or *G. tachinoides* in the transmission of trypanosomiasis of stock.

The receding of the Ashanti forest and the present development of the Colony may cause even greater contact between this species of tsetse and man. The main policy for control should lie in improving and controlling the natives' methods of cultivating the bush. Farms should be as close to the village as possible, contiguous, and kept under cultivation, if possible, permanently. Clearings should be made of at least 100 yards width round bush villages, and of at least 200 yards width round important towns. Small clearings and isolated farms are considered a danger.

10. Acknowledgments.

It is with great pleasure that the writer takes this opportunity of acknowledging the stimulating advice and help given him by Professor P. A. Buxton, both through correspondence and, later, personally, during the writing of part of this paper at the London School of Hygiene and Tropical Medicine. The writer is further deeply indebted to Miss H. M. Woods, of the Statistical Department of the same School, for the great trouble she took in teaching him the statistical methods involved, and in checking his calculations.

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THE CONDITIONS OF SEXUAL MATURATION IN THE MIGRATORY LOCUST.

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In a previous paper (Pospelov, 1926a) I pointed out that adult locusts (*Locusta migratoria migratoria*, L.) kept in a cage at a constant temperature of 35–38°C. (95–100°F.) and at sufficient humidity attained sexual maturity in a month, while those kept at 20–30°C. (68–86°F.) failed to mature even after three months.

Similar dependence of sexual maturation on the temperature can be observed in nature. According to Predtechenskiĭ (1928) in Central Russia the mean temperature of about 18°C. during the imaginal period of the locust determines the limit of possible maturation, and the locusts remain infertile if the temperature does not attain that minimum.

In the autumn, when the temperatures are low (14–21°C.) maturation in the gregarious phase of the locust is observed during the migrations. According to Zriakovskii (1926), the migrating locusts in the Northern Caucasus were all sexually immature in September 1926. I have observed in the same country, in September 1924, the end of the migration period, when a swarm settled on a maize field and fed on the green leaves. Copulation was observed and the ovaries were found to be well developed, though no oviposition had yet commenced. This I explained (Pospelov, 1926) by the probable raising of the body temperature of the locust during flight. Strel'nikov's (1932) investigations of the body temperature of the locust by means of a thermoelectric needle confirmed this suggestion, since the temperature in the thorax of a locust was observed to rise by 10°C. after a flight. Thus the mass migration of locusts leads to a meeting of the opposite sexes, and during the resting of the swarms feeding and copulation take place.

Already in 1924 I found that male locusts mature during the first days of the adult stage and commence to copulate with females when the latter are still immature. It appears that without copulation the females would remain immature, in spite of the sufficiently high temperature, and the following experiment proves that this is actually the case.

On 6th May 1929, three females bred from eggs in the laboratory were placed in a cage and kept for three months, first in a room, and from July onwards in an outdoor insectarium. The temperature during May and June fluctuated from 21° to 30°C., and in July from 21° to 40°C. In a control cage, where males were kept with females under the same conditions of temperature, maturation occurred in a normal way, and in July the females died after ovipositing.

The females kept separated from males were very inactive in spite of the high temperature, and dissections of two females proved that until August their ovaries remained at the stage observed at the beginning of the adult period.

On 3rd August two males taken in the field were placed in the cage with the remaining female. A few days later copulation was observed and on 11th August the first batch of eggs was laid. On the 21st a second batch was deposited and the female remained alive until early September.

The experiment shows that by isolating females from males the life of the former can be extended, but the maturation of eggs in them retarded. On the other hand, it shows that temperature alone does not cause the maturation, unless copulation has taken place. Fertilisation in itself is a factor which permits the maturation of eggs.

In connection with this experiment, some observations were made on the mechanism of fertilisation in the locust.

The spermatophore fertilisation in the Migratory Locust has been described by Sokolov (1926) and Boldyrev (1929). According to their descriptions the tubular portion of the spermatophore penetrates into the receptaculum seminis and the sperm passes from one to the other. The tubular portion of the spermatophore, after fertilisation, breaks off from the reservoir remaining with the male and blocks up the canal of the spermatheca. After repeated copulations up to three such stoppers may accumulate and block the canal for several weeks, making it difficult for the spermatozooids to pass from the spermatheca into the oviduct, without, however, preventing the maturation of the eggs and their fertilisation.

My observations on the development of eggs after their fertilisation proved that the sperm accumulates in the calyces of the ovary in such quantities that the calyces bulge perceptibly. Compared with this quantity, that of the sperm in the apical section of the spermatheca is at that period very small. There are no spermatozooids at that time in the lower section of the spermatheca, where only the albuminous fluid with yeast-like cells is present.

The accumulation of the sperm in those parts of the calyces where the egg-chambers open into them enables the sperm to reach the eggs before they pass out into the oviducts. It appears that the penetration into the eggs of the fertilising fluid, which consists of spermatozooids and the secretions of the male accessory glands, has a connection with the maturation of the eggs.

While passing out of the egg-chambers into the calyces, the eggs have to pass through the accumulation of the sperm which enters the oviducts with them, and when the eggs are laid, forms a part of the foamy mucous fluid, usually composing the egg-pod. That this fluid is derived not only from the female, but from the male as well, is shown by the presence of bundles of spermatozooids in the hardened foamy covering of the egg-pod.

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FERTILITY AND CLIMATIC ADAPTATIONS IN SIBERIAN GRASSHOPPERS.

By I. A. RUBTZOV.

Introduction.

The present studies were carried out in order to find out the potential and actual fertilities of grasshoppers, and to determine their rôle in outbreaks. This work led to the discovery of a number of interesting facts of ecological and morphological correlations between the ovaries and the habitat.

The investigations were made on the most common East Siberian grasshoppers (see list below).

The potential fertility of females taken in the field under different ecological conditions was determined by counting the ovarioles and egg-tubes under a binocular, with a magnification of 100. In order to avoid those females which had already oviposited, the adults of each species were collected as soon as they made their appearance. The number of specimens studied for each species was not less than ten (with the exception of *Podisma koeppeni*, Zub.—3 specimens, *Stenobothrus lineatus*, Panz., and *Prumna primnoa*, F. W.—4 specimens each). In the case of *Chorthippus albomarginatus*, De G., and *Ch. biguttulus*, L., from 60 to 200 specimens were studied.

To determine the actual fertility, for several seasons newly moulted males and females were kept until their death in outside wire cages. In addition, an attempt was made to find the average number of egg-pods to a unit of area with a determined density of adult population.

The earlier studies (Morse, 1904, 1907, and Vestal, 1913, in North America ; Baranov & Bei-Bienko, 1926 ; Bei-Bienko, 1930 ; Vinokurov & Rubtzov, 1930 ; Rubtzov, 1932, in Siberia) have shown that, in accordance with its requirements, each species lives in a more or less definite habitat, characterised by certain humidity, height and density of vegetation, etc. It has even proved possible in the case of some Siberian grasshoppers to establish the indicators, such as a plant, or a group of plants, characteristic of the optimum habitat (reservation) of a given grasshopper species, or association of species. The distribution of the grasshopper species in habitats is determined chiefly by microclimatic conditions, primarily by the air and soil humidities. On the basis of the earlier studies (see above) the grasshoppers of the East Siberian forest-steppe zone can be divided into four groups, in accordance with the humidity of the station inhabited :—

Hygrophiles	Mesophiles	Xerophiles	Extreme Xerophiles
<i>Mecosthetus grossus</i> , L.	<i>Prumna primnoa</i> , F. W.	<i>Aeropus sibiricus</i> , L.	<i>Bryodema tuber- culatum sibi- ricum</i> , Iconn.
<i>Chorthippus longi- cornis</i> , Latr.	<i>Arcyptera fusca</i> , Pall. <i>Euthystira brachy- ptera</i> , Ocsk.	<i>Dasyhippus varie- gatus</i> , F. W.	<i>Arcyptera micro- ptera microptera</i> , F. W.
<i>Acrydium kraussi</i> , Saulcy	<i>Podismopsis pop- piusi</i> , Mir.	<i>Stenobothrus eur- asius</i> , Zub.	

Hygrophiles	Mesophiles	Xerophiles	Extreme Xerophiles
<i>Podisma koeppeni</i> , Zub.	<i>Chorthippus paral-</i> <i>lelus</i> , Zett.	<i>Stenobothrus nigro-</i> <i>maculatus</i> , H. Sch.	
	<i>Chorthippus bigut-</i> <i>tulus</i> , L.		
	<i>Chorthippus apri-</i> <i>carius</i> , L.		
	<i>Gomphocerus rufus</i> , L.		
	<i>Omocestus haemor-</i> <i>rhoidalis</i> , Charp.		
	<i>Omocestus viridulus</i> , L.		
	<i>Stenobothrus linea-</i> <i>tus</i> , Panz.		
	<i>Celes scalozubovi</i> , Adel.		
	<i>Psophus stridulus</i> , L.		

As is to be expected in a forest-steppe zone, the majority of species belong to the mesophiles. Hence all these species, as well as *Aeropus sibiricus* and *Chorthippus longicornis*, can be regarded as the typical "zonal" species (*i.e.*, typical of that zone; see Bei-Bienko, 1930). *Bryodema tuberculatum sibiricum*, *Stenobothrus nigromaculatus*, *S. eurasius*, *Arcyptera microptera microptera*, are emigrants from the south, the first three from Mongolia, the last from the steppes of Asia. The other species, *viz.*, *Dasyhippus variegatus*, *Mecostethus grossus*, *Acrydium kraussi*, *Podisma koeppeni*, apparently find their optimum conditions further to the north, in the forest zone, and probably extend beyond the Arctic circle. Both the emigrants from the south, and the inhabitants of the more northerly regions, can be considered as the "extra-zonal" elements in the forest-steppe zone.

Bei-Bienko (1930) has shown that the optimum stations inhabited by the same species in different zones are subject to a certain displacement. Thus, when the xerophilous species of the forest-steppe zone occur in the more southerly ones, they tend to inhabit more mesophytic stations, or occupy areas of greater elevation, thus securing for themselves equivalent microclimatic conditions. The reverse process takes place in the more northerly zones, where the species that are mesophilous in the south occupy relatively more xerophytic stations. For example, *Aeropus sibiricus* occupies xerophilous stations in its own steppe-forest zone, but to the south of it, in Turkestan, it occurs in the mountains. On the other hand, *Arcyptera microptera microptera*, which finds the optimum conditions further south (in Kazakstan), occupies there the medium, sometimes mesophilous stations, while in the north, in the East Siberian forest-steppe, it occurs in the extreme xerophilous ones. All this shows that for grasshoppers the most important factor is not a given plant association, but definite microclimatic conditions which are subject to zonal displacement, *viz.*, into the more xerophilous stations in moving northwards, and the more mesophilous stations in moving southwards.

Adaptations in Ovaries.

It appears that the total numbers of eggs, of egg-tubes, and of eggs in each tube, are very unstable quantities, varying in different genera and species, as well as in

individuals belonging to the same species but inhabiting different parts of its area. The following table gives the average data for the majority of the common grasshoppers collected in one habitat in Eastern Siberia (Irkutsky Zernosovkhoz):—

TABLE I.

Species	Number of egg-tubes	Number of eggs in egg-tube	Total number of eggs
<i>Euthystira brachyptera</i> , Ocsk.	3+3	20-26	120-128
<i>Dasyhippus variegatus</i> , F.W.	3+3	22-26	140-150
<i>Stenobothrus lineatus</i> , Panz.	3+3	25-29	152-160
<i>Stenobothrus nigromaculatus</i> , H. Sch.	4+4	20-22	160-170
<i>Stenobothrus eurasius</i> , Zub.	4+4	21-23	168-180
<i>Omocestus viridulus</i> , L.	5+5	27-29	270-290
<i>Omocestus haemorrhoidalis</i> , Charp.	5+5	16-19	160-180
<i>Podismopsis poppiusi</i> , Mir.	5+5	21-24	210-230
<i>Chorthippus albomarginatus</i> , De G.	5+5	17-20	170-200
<i>Chorthippus dorsatus</i> , Zett.	5+5	15-17	150-164
<i>Chorthippus scalaris</i> , F. W.	5+5	15-20	148-166
<i>Chorthippus longicornis</i> , Latr.	5+5	14-18	140-160
<i>Chorthippus parallelus</i> , Zett.	5+5	16-18	120-140
<i>Aeropus sibiricus</i> , L.	5+5	21-23	210-228
<i>Acrydium kraussi</i> , Saulcy	5+5	14-18	148-152
<i>Chorthippus biguttulus</i> , L.	5+6, 6+6, 6+7, 7+7	15 20	150-248
<i>Podisma koeppen</i> , Zub.	7+7	6 9	84-100
<i>Arcyptera microptera microptera</i> , F. W. ...	8+8, 8+9	11-14	200-250
<i>Chrysochraon dispar</i> , Germ.	10+11	10-11	200-230
<i>Celes scabozubovi</i> , Adel.	11+11	11-13	220-240
<i>Bryodema tuberculatum sibiricum</i> , Ikonn. ...	12+12	12-14	264-312
<i>Arcyptera fusca</i> , Pall.	12+13	12-13	240-280
<i>Prumna primnoa</i> , F. W.	14+14, 14+15	9-10	240-288
<i>Mecostethus grossus</i> , L.	13+13	10-12	286-338
<i>Psophus stridulus</i> , L.	13-17+13-17	6-7	260-312

As may be seen from the table, the number of egg-tubes in each ovary varies from 3 in *Euthystira brachyptera* and *Stenobothrus lineatus*, to 17 in *Psophus stridulus*, and in the majority of species there are 5 egg-tubes on each side. There is an interesting variation in the number of egg-tubes in *Chorthippus biguttulus*. All the other species

of this genus have a more or less constant number of egg-tubes, viz., 5+5, but in the specimens of *Ch. biguttulus* studied by us it was 5+6, 6+6, 6+7 and even 7+7. As stated by Dufour (1841), the number for Western Europe is 6-7. There are still greater differences in species with more than 10 egg-tubes. The variations within a genus are given in the table for *Stenobothrus lineatus* and other *Stenobothrus* spp., *Arcyptera microptera microptera* and *A. fusca*, and others. It follows that the number of the egg-tubes in different species is not constant, and not always correlated with the present classification.

The number of eggs in every egg-tube varies from 25-29 (in *Stenobothrus lineatus* and *Omocestus viridulus*) to 6-7 (in *Psophus stridulus*), and it will be noticed that the numbers of tubes and of the eggs in a tube vary inversely. Such a correlation has an obvious ecological significance, for the average total number of eggs required for the preservation of the species remains more or less constant (from 150 to about 250 in the East Siberian grasshoppers). If these data are compared with the character of the habitats, it will be seen that amongst the zonal species a large number of egg-tubes (over five) is, as a rule, characteristic of the mesophilous species, breeding in a cool habitat (*Mecostethus grossus*, *Arcyptera fusca*, *Prumna primnoa*, *Podisma pedestris*, *Psophus stridulus*). On the other hand, few egg-tubes (5 and less) are found most frequently in xerophilous species (*Dasyhippus variegatus*, *Stenobothrus* spp., *Gomphocerus* spp., *Myrmeleotettix palpalis*). The extra-zonal species present an exception to this rule, e.g., *Bryodema tuberculatum* and *Arcyptera microptera microptera* have a large number of egg-tubes, although they breed in xerophytic stations. However, if it is remembered that these species are derived from the southern steppes, and that the forest-steppe of Eastern Siberia represents the northern margin of their distribution area, and that, moreover, the microclimatic conditions of the xerophilous stations in the forest-steppe are equivalent to those of the mesophytic ones in the steppe proper, these exceptions will not break the rule, but will merely serve as illustrations of the zonal displacement discussed in the introduction.

These species which have few egg-tubes while inhabiting a mesophytic station (*Euthystira brachyptera*, *Stenobothrus lineatus*, *Omocestus viridulus*, *Acrydium kraussi*, *Podismopsis poppiusi*, *Chorthippus longicornis*) always have their life-cycle and particularly their egg-laying period, adjusted to the seasonal cycle. For instance, the representatives of the genus *Acrydium*, inhabiting the birch and pine forests, pass the winter in the adult and larval stages, so that in spring the adults are ready to take full advantage of the scanty available warmth. *Podismopsis poppiusi* and *Omocestus viridulus*, which often occur in the same habitat with the *Acrydium*, hatch early in the spring, as soon as the soil becomes slightly warmed, i.e., they have a low zero of development. This is further confirmed by field observations and by special experiments (Rubtsov, 1934, unpublished). Unlike all the other grasshoppers, the genus *Chrysochraon* does not oviposit in the soil, but in the stems of plants in mesophytic stations, thus subjecting them to a warmer microclimate. Further, all the species possessing few egg-tubes and inhabiting mesophytic stations have a greater longevity. Thus the hygrophilous *Chorthippus longicornis* and the mesophilous *Ch. apricarius* appear during the first half of June, together with the xerophilous *Aeropus sibiricus*, but continue to oviposit until August, by which time all the xerophilous species have finished laying.

All the various adaptations enumerated above can be understood if we assume that a more or less constant quantity of heat is required in different species for the maturation of the eggs, and that in the forest-steppe zone this quantity is at its minimum. It must be remembered that the grasshoppers, as a group, have relatively high heat requirements, and that they have probably spread from south to north, the number of species decreasing northwards.

From the above it can be presumed that the same species will have a different number of egg-tubes and of simultaneously maturing eggs under different ecological

conditions in different parts of its geographical area, and that, theoretically, this number should decrease from north to south. This suggestion is supported by data from the literature, as well as by my investigations of the ovaries of specimens collected in different parts of the geographical areas. For instance, at the northern margin of its area in Eastern Siberia, *Bryodema tuberculatum* has 12+13 egg-tubes, and deposits 22-25 eggs in each egg-pod. In Western Siberia Bezrukov (1923) counted 15-22 eggs to each egg-pod. Moritz (1915) indicated only 8-9 eggs in one egg-pod for the same species in the more southern districts, namely Turgai region (Kazakstan). On the other hand, in the extreme Far East, and in Western Europe, which are both characterised by a more humid and cooler climate, the number of egg-tubes increases. Thus, in two specimens of *Bryodema tuberculatum* collected in Trans-Baikalia (on the middle course of the River Shevlja), I counted 16+17 egg-tubes. Similar changes have been observed in a number of other species. For example, *Mecostethus grossus* has 12+12, 12+13 and 13+14 egg-tubes in the European part of Russia and in Eastern Siberia, but in the Far East the number is 16+16. *Oedipoda coerulescens* has 10+10 egg-tubes in the European part of Russia, and 16+16 in Western Europe (Dufour, 1841). In *Chrysochraon dispar* there are 10+11 egg-tubes in the Volga region, but in Western Europe there must be at least 12+13, according to Ramme's (1927) figures. The same can be supposed for *Acrydium kraussi*, which in England lays 11-12 eggs (Lucas, 1920), instead of the 10 in Eastern Siberia. It is probable that similar changes could be discovered in the majority of species, particularly in those with more than 10 egg-tubes in each ovary (e.g., *Dociostaurus maroccanus*, *Calliptamus italicus*, *Locusta migratoria*). At the same time the relative stability of the number of egg-tubes in those species in which it is not above 5 for each ovary must be mentioned. Thus in *Aeropus sibiricus* and *Chorthippus albomarginatus* their number was found to be constant in specimens from the Far East (*A. sibiricus* subsp. *kudia*), from Yakutia, from the Eastern and Western Siberia and from the Volga region.

The tendency towards increase in the number of egg-tubes in the more southerly and desert forms is in apparent contradiction to the above statements. Thus in *Calliptamus italicus* and in *Dociostaurus maroccanus* and allied species, the total number of egg-tubes is about 30, and in *Locusta migratoria* and *Schistocerca gregaria* even above 100. But if one takes into consideration the ecological conditions of the semi-desert, one can regard this as an adaptation to the extremely sharp fluctuations in the microclimate, and to the short duration of the conditions suitable for oviposition. All this necessitates a large supply of simultaneously maturing eggs, and this is achieved by increasing the number of egg-tubes.

Potential Fertility.

There is no noticeable difference in the total number of eggs, or in the potential fertility (determined by dissecting the ovaries and counting the eggs) in grasshoppers collected in different habitats. The data presented in Table I were obtained from grasshoppers taken on the outskirts of a pine forest, in a luxurious mesophytic vegetation on the one hand, and on a pasture-land with scanty xerophytic growth, on the other. It can be concluded, therefore, that the habitat has no marked influence on the potential fertility, which is probably hereditary.

On the other hand, the actual fertility, i.e., the number of developing egg-tubes and of deposited eggs, does not correspond to the potential fertility, is very variable, and depends on such factors as food, microclimate, etc. The data concerning this point will be discussed later (see page 346).

Turning now to the consideration of potential fertility (Table I), we see that the total number of eggs varies from 100 to 300. It must be pointed out at once that there is no correlation whatever between the potential fertility of a species and its abundance in nature. Indeed, the most abundant species (*Aeropus sibiricus*, *Chorthippus albomarginatus*, *Stenobothrus nigromaculatus* and others) possess a medium, or even less

than a medium, number of eggs (120–190), and the greatest numbers are found in the species occurring but rarely (*Mecostethus grossus*, *Psophus stridulus*). This suggests that the potential fertility cannot be regarded as an index of the potential increase in the numbers of a species, but merely indicates the degree of the controlling action of the environment. The coefficient of destruction by the controlling factors must be higher in the East Siberian forest-steppe zone for such relatively rare species as *Mecostethus grossus*, *Psophus stridulus*, and *Bryodemus tuberculatum*, than for *Chrysocraon*, *Euthystira*, or *Stenobothrus* spp., which have a smaller potential fertility but are more abundant than the former. It should be noted that these abundant grasshoppers possess special adaptations, for, as has been already mentioned, *Chrysocraon* lays its eggs in the stalks of plants, and *Stenobothrus* spp. make a special capsule of excreta to cover the usual frothy envelope of the egg-pod (Goncharova, 1933).

It is of interest to compare the potential fertility of *Locusta migratoria* with that of our Siberian grasshoppers. In *Locusta migratoria rossica* from Central Russia, I counted 53+52 egg-tubes, with 12–13 eggs in each, i.e., 1260–1365 eggs. In *Oedipoda coerulescens* the figures were 10+10 egg-tubes, with 20–26 eggs in each, or 400–520 eggs. The potential fertility of the ACRIDIDAE from the more arid zone is, therefore, much higher than in the Siberian species.

Actual Fertility.

Maltsev (1925) investigated the actual fertility of the Siberian grasshoppers, and obtained the following data for *Chorthippus albomarginatus* :—

1923: 21, 13, 22, 16, 18—average 18 egg-pods per female. 1924: 13, 0, 2, 16, 14, 8—average 14 egg-pods per female. A similar figure (15 egg-pods per female) was given by Berezhkov (1924). Therefore, if we take the average number of eggs in every egg-pod to be about 7, the actual fertility will be equal to 100–110 eggs, as against 170–200 potential eggs (see Table I).

Our special cage experiments to determine the actual fertility of different species, as well as the dissections of specimens in the field at the beginning and before the end of the egg-laying period, show that, on the average, only half, and often less than half, of the total number of eggs present in the ovaries are deposited. In favourable conditions this number varies from 50 to 100 (or six to twelve egg-pods for species with ten egg-tubes). On the basis of such fertility, the coefficient of destruction can be determined by Bremer's formula (see Uvarov, 1931) :—

$$q_c = \left(1 - \frac{b^c}{a}\right) \cdot 100 = 96-98 \text{ per cent.}$$

where q is the coefficient of destruction, a the number of the progeny of one female (50–100), $b = 2$, the ratio of the females, and $c = 1$, the number of generations a year. The coefficient of destruction for the Siberian grasshoppers is, therefore, very high and equal to 96–98 per cent.

The actual fertility of a species differs in different habitats in so far as the controlling factors, e.g., the parasites, the microclimate, and the food, are different.

The Influence of Parasites.

The following three groups of parasites are of the greatest importance to the larvae, and particularly to the adults of the Siberian grasshoppers* :—

1. TACHINIDAE (especially *Blaesoxipha lineata*, Fall.).
2. Roundworms (*Mermis* spp.).
3. Red Mites (TROMBIDIIDAE).

*Fungous diseases of adult grasshoppers can be ignored, for in normal years the percentage of infestation is very low, probably less than one per cent. It is only in exceptional years, towards the end of an outbreak, that mass infestation, particularly in certain species (e.g., *Podisma pedestris*) has been observed. Fungous diseases of egg-pods appear to be of great controlling value, but this problem will be discussed in another paper.

The importance of the parasites has so far been determined only for the Migratory Locust, *Locusta migratoria*, L. (Olsuf'ev, 1929 ; Nikolskii, 1925 ; Popova, 1932, and others). These authors came to the conclusion that the above parasites, even if they do reduce the egg-production, do not entirely prevent it, and the females infested by mites, or even by a fly, retain their ability to lay at least a few healthy eggs. However the same parasites that are relatively harmless to the Migratory Locust are fatal to the Siberian grasshoppers. This is evidently due to the considerable difference in size, for the locust is at least 10 times as heavy as an average grasshopper.

Dissections of grasshoppers infested by *Blaesoxipha lineata* invariably disclosed a pronounced under-development of the ovaries. Thus, the number of eggs in *Aeropus sibiricus* is 210 to 228, but in parasitised specimens it drops to 120-140, the eggs being abnormally pale and small. The fat-body remains undeveloped even when the parasite is only 2-2.5 mm. long. Fully developed eggs have never been observed, and the general exhaustion of the infested grasshopper brought about by its restricted feeding and the destruction of its tissues by the parasite, preclude, in my opinion, the possibility of the maturation and the laying of eggs, except in those rare cases when the parasitism takes place very late, and the first lot of eggs become mature before the parasitic larva reaches any considerable size. As is well known, the fly larva usually emerges by boring through the thin membrane between the head and prothorax, and causes the death of the host. This has been observed in *Aeropus sibiricus* and *Chorthippus albomarginatus*, and should be true of other grasshoppers, which as a rule are even smaller in size. Thus an early attack by a Tachinid usually leads to complete sterility and death.

Parasitism by Nematodes (*Mermis* spp.) is very sporadic. In the year 1933, which had a very dry July, only two worms were found in the 300 dissected specimens of *Chorthippus albomarginatus*. However, in previous years I have observed the parasitism of this species to reach 50 per cent. in some humid stations near the river. According to Uvarov (1928) the ovaries of the female locusts infested by Nematodes fail to mature, and this must obviously be true of the small Siberian grasshoppers. The abdomen and thorax of an infested grasshopper are sometimes completely filled by the coils of the worm (reaching up to 10 cm. in length, with a diameter of less than 1 mm.), and the remains of the ovaries and fat-body can be found only with difficulty. It may, therefore, be concluded that the fertility of the infected females is nil, although this matter has not yet been studied experimentally. But in spite of the profound effect which the Nematodes have on infested individuals, they cannot be regarded as the main controlling factor of the Siberian grasshoppers, for as a rule the parasitism does not exceed 10 per cent. (Rubtsov, 1934), and is usually only 3-5 per cent.

Mites do not have any considerable influence on the Migratory Locust, the infested females of which are able to lay eggs (Popova, 1932). I have observed an infested *Aeropus sibiricus* laying eggs, and the dissection of the females bearing one or two small mites did not disclose any noticeable under-development in the ovaries. A different picture is presented, however, when there are 10-20 or more mites on one individual. The grasshopper endeavours to get rid of the parasites by constantly flapping the elytra and wings, which get worn and reduced to about a third of their length. It feeds but little, and constantly crawls about, apparently owing to the irritation caused by the mites, thus losing a great deal of energy. Moreover the feeding of 20-30 mites at the expense of the host also affects the latter. The dissection of females bearing more than 10 mites disclosed the absence of the fat-body and a pronounced under-development or other abnormalities of the ovary. When infested by a large number of mites the female is unable to lay eggs, even if they reach maturity, and in such cases the eggs perish, assuming at first a brown and then a black colour and blocking up the oviducts. The ovaries themselves apparently undergo some process of decomposition, for they become watery and the eggs lose shape and become liquid. The females so affected usually bear at the tip of the abdomen small bits of a hardened foamy substance stopping the opening of the vagina. These may

be due to the foamy substance drying up when the female could not complete oviposition owing to the restlessness caused by the mites, and the stopping of the vagina may have brought about the decomposition of the ovaries and eggs. This would eventually cause the death of the insect.

The Influence of the Microclimatic Conditions.

Although the potential fertility is the same in the habitats with different microclimates, the variations in the microclimate have a very marked effect on the actual fertility. There are, unfortunately, no thorough experimental studies or exact observations on this point for Siberian grasshoppers. Theoretically, it appears very probable that the warm, dry, sunny weather, by raising the activity increases the consumption of food and thus leads to a larger egg-production. Cold, wet, cloudy weather, on the other hand, should have the opposite effect.

This is confirmed by observations on different species of grasshoppers kept in cages. Those in cages standing in a shed where there was less sunlight and the air was cooler and more humid than outside, laid only one or two egg-pods per female, in spite of abundant food. The same species kept in cages standing outside in full sunlight laid 3-5 or more egg-pods per female. A similar difference should be observed in a shady forest and an open sunny pasture-ground, in dense and open grass-land.

The Influence of Food.

Comparing the fertility of grasshoppers in reservations where the insects are very abundant every year, with that in mesophytic stations where they always occur singly, we come to the, at the first glance, paradoxical conclusion that as a rule fertility is lower in reservations than elsewhere. This happens not so much because of parasites (chiefly Diptera, *Blaesoxipha* in adults and *Systoechus* in egg-pods), although the percentage of infestation is higher in reservations than outside them, as on account of the lesser number of developing egg-tubes, probably owing to lack of food. By placing six fertilised females in one cage (30 by 18 by 24 cm.) and providing them with plenty of food, and at the same time placing twelve other fertilised females in a similar cage and giving them but little food, the following figures were obtained :—

TABLE II.

					Number of egg-pods in cages	
					with plentiful food 6 "	with little food 12
Pods with 10 eggs	...	...	...	...	1	—
" 9 "	...	...	...	...	6	—
" 8 "	...	...	...	...	12	3
" 7 "	...	...	...	...	10	8
" 6 "	...	...	...	...	2	5
" 5 "	...	...	...	...	—	3
" 4 "	...	...	...	...	—	1
" 3 "	...	...	...	...	—	1
Total number of egg-pods					31	21
" " eggs	...	...	...	...	242	132
Average number of eggs per egg-pod					8	5
" " " one female	...	...	...	...	60	11

The number of egg-pods per female in the first cage with plenty of food was 5, and in the second only 1.8. But the main difference was in the quality of the egg-pods. In the first cage they contained mostly 7, 8 and 9 eggs, and in the second 6 and 7. The average number of eggs per female in the first cage, with plenty of food, was 60,

or over five times as much as in the second cage. The dissection of dead females from the second cage showed that their ovaries were not quite mature and contained only 6-7 fully developed egg-tubes instead of 8-10, the other egg-tubes remaining apparently sterile.

In reservations where the population of *Chorthippus albomarginatus* surpasses 50 to one square metre, starvation has a marked influence, similar to that observed in second cage. In 100 females taken from such a reservation, the ovaries had on the average only 5 developed egg-tubes. On the other hand, in 30 females collected only 80 metres away from the reservation, in dense grass where the population was not more than 5 individuals to 1 sq. metre, the ovaries had on the average 9.1 developed egg-tubes. This means that the fertility was twice as great in the habitat with abundant food as in the reservation where food was scanty. The opening of the egg-pods collected in the reservation confirmed this conclusion, for most of them contained 5-6 eggs. A similar picture was observed for other species in other habitats in 1933 and the preceding years. Thus, the actual fertility of grasshoppers is by no means greater in reservations than outside them, and is very probably lower.

In spite of all this, outbreaks occur in the reservations nearly every year, while in the stations with luxurious grass but with unfavourable (apparently microclimatic) conditions, the grasshoppers are met with in single specimens. This leads to us the conclusion that the main factors determining the fluctuations in the numbers of grasshoppers are climatic and microclimatic conditions to which the hibernating eggs are subjected. Fertility plays but a secondary part in determining the outbreaks, and its magnitude indicates rather the degree of the controlling influence of the environment on the increase of population.

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Summary.

1. The number of egg-tubes and the number of eggs in each tube varies in accordance with the food and the climatic and microclimatic conditions of each habitat. The majority of Siberian grasshoppers have adaptations in the ovaries which enable them to take full advantage of the available heat.

2. In the species possessing 10 or more egg-tubes, their number varies in different parts of the distribution area. It decreases towards the centre of the area with increasing warmth and dryness, and increases towards the colder and more humid margins of that area (e.g., in the Far East and in Western Europe).

3. The potential fertility is more or less stable in different species of grasshoppers, and in the species studied it fluctuates between 84 and 388 eggs per female.

4. There is no correlation between the potential fertility and the abundance of the species in nature, for the greatest fertility is met with in those species which occur but rarely. The injurious (i.e., very numerous) grasshoppers have a medium, or somewhat less than a medium, potential fertility.

5. The actual fertility is greatly dependent on the environment and has a wide range of fluctuation.

6. Lack of food in reservations was observed to lower the fertility of grasshoppers by 30-40 per cent. The parasites (*Blaesoxipha* spp., *Mermis* spp.) greatly reduce the degree of fertility of the Siberian grasshoppers. However, the percentage of infestation by these parasites is low, but in the reservations it is somewhat higher than outside. Thus, the actual fertility in reservations is rather lower than outside.

7. The outbreaks of the Siberian grasshoppers are determined by the climatic and microclimatic conditions. The fluctuations in fertility never have any real importance in causing the outbreaks. Lack of food, parasites, predators and diseases are of minor importance; among the latter the main factors are the diseases of the egg-pods, which again depend on the microclimate.

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INVESTIGATIONS ON THE CONTROL OF THE AMERICAN AND RED BOLLWORMS OF COTTON IN S. AFRICA.

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(PLATE XI.)

Introduction.

The investigations described in this preliminary paper cover the period 1929–1932. The work commenced with the breeding and experimental releases of the egg parasite, *Trichogramma lutea*, Gir., and other egg and larval parasites of both the American Bollworm, *Heliothis obsoleta*, F., and the Red Bollworm, *Diparopsis castanea*, Hmps. In the course of field experiments designed to evaluate the usefulness of released parasites, it was found necessary to intensify very appreciably methods of recording insect material and to extend observations widely in nature and scope. Some of the factors for consideration were found to be :—the duration of oviposition on different food-plants of the bollworms, the particular condition of plant growth, if any, associated with oviposition, the relative attractiveness of food-plants, and other matters which, in general, may be termed bollworm-plant relationships.

Although the parasites studied were regarded primarily as agents to be employed in cotton fields for the reduction of pests there, later observations suggested using them in various other crops that are grown prior to, or concurrently and in association with, cotton. Investigations were extended correspondingly, and out of the needs of our parasite investigations, there has arisen a system of continuous and quantitative survey of the course of bollworm activity over a wide field. As data have accumulated, it becomes clear that the information derived from methods of survey, such as have been adopted, is an essential foundation to field work on bollworm control, including the exploitation of parasites. The data obtained are serving to state the problems and thus, for the time being, this work has superseded in importance other investigations on bollworms at Barberton.

The purpose of the present paper is to describe the methods in use and to report upon the information obtained.

Methods of Field and Laboratory Surveys.

The course of oviposition is the best indication in point of magnitude, duration and time of occurrence in the life of a food-plant upon which to study the relations between the pest and the plant. The high mortality amongst larvae, which varies in different crops, makes computations and comparisons of the incidence of the bollworm in a crop most inaccurate if based on larval records only. While it is quite possible to estimate closely the numbers of larvae in an area of crop on successive occasions, the mortality, particularly amongst first and second instar larvae, may be such that in the absence of egg records the course of moth activity is obscured. Furthermore, the migratory movements of larvae introduce other complications. In studying the relative attractiveness of plants to moths the course of oviposition must be observed closely.

Eggs laid by both American and red bollworm moths are most unevenly distributed over a crop, *vide* Pl. xi. The discontinuous egg deposition commonly found is correlated with conditions of vegetative and reproductive growth which need not be considered at present. In view of this, however, a sampling procedure has

been adopted that allows information to be drawn from all sections of a field. The method is to mark off each field into numerous blocks of convenient size and to sample each block. In parasite release and other experimental work Clapham's method (1929) and randomised block methods of sampling have been adopted. For routine field records, however, plants are marked systematically in each block according to what appears to offer the best representation for the size of sample taken. The size of the sample in routine survey work has been, as a rule, 16 plants to the acre. In certain experiments it has been possible, with the aid of additional observers, to make records on 64 plants per acre, giving in these cases a 1 per cent. sample of the plant population.

In work of this nature the size of the sample taken must depend largely upon the number and ability of available recorders. Very considerable strain and fatigue are involved in searching plant surfaces for the eggs of the bollworm moths, and the number of record plants allotted to observers must be decided upon experience of what may be attempted for each different type of plant growth. In practice we have apportioned 96 plants per observer per day in tall growing crops such as maize and sunflower, and half that number of cotton, groundnut, bean and other plants. These numbers are based upon the time and labour required to examine properly the full-sized plant of each kind in the heat of summer, especially during periods of heavy oviposition. Consequently in order to conduct surveys of this nature a large staff of observers is required. This is supplied by natives specially selected and trained to do the work under European supervision. It may be accepted that trustworthy results are supplied by the class of observer available, when they are supervised properly. Their work is to see, count and enter numbers on record sheets and to collect regularised samples of egg and larval material. In practice the system operates satisfactorily, and native recorders undoubtedly withstand the prolonged tedium of such work infinitely better than Europeans.

Egg Populations.

Observations on egg-laying by American bollworm moths require to be made at least twice weekly. If the interval between records exceeds four days, hatching of eggs occurs under summer temperatures and records are lost. The incubation period of the egg of the red bollworm moth is somewhat longer but, as it facilitates drawing up a recording programme, these are also recorded twice weekly.

In routine work it is customary for observers to collect a sample of 50 eggs off the plants of record, brushing off those uncollected. The collected eggs are placed in gelatine capsules, when collected, and brought to the laboratory and placed in an incubating chamber for observations on the extent of egg parasitism under natural conditions and the identity of the parasites concerned. This procedure enables the construction of a continuous record of the course of egg parasitism by different parasites over a wide range of orchard and field crops, together with various important data on the parasites themselves. In recording work connected with releases of egg parasites it is necessary to obtain information on the fate of egg populations as they occur on the plants. In order to secure this, the eggs observed must be left *in situ*. It is then necessary to distinguish between eggs already recorded and others laid between dates of record, and this is accomplished in the case of maize, sunflower and other suitable plants by marking eggs with a special type of pin. These pins are known commercially as draper's pins, and they may be procured with glass beaded heads in a range of colours, one of which may be assigned to each day of the week. Pins are inserted in the epidermal tissues of the leaf, stem, etc., at egg positions so that the egg lies over the line of insertion. Eggs in positions where pins are unsuitable, for example, on maize silk, are marked by pieces of cotton thread of the appropriate colour.

Eggs on cotton, bean and other plants, where egg-laying sites or foliage conditions prevent the use of pins, are marked conveniently with small cardboard tags of different colours. This system of marking eggs and differentiating between oviposition periods has proved very satisfactory.

In all instances the growth condition of a crop under survey is recorded weekly, the reproductive phase of the plants being of particular importance as referred to later.

Where the inter-row and inter-plant intervals are alike, as is frequently found in cotton and maize, the egg-laying on equal samples of plants may be compared directly, as the plants occupy equal unit areas. Eggs recorded on equal samples of plants set out at different spacings are, if comparative weight of oviposition is being considered, brought to a common basis of unit area. Orchard crops are sampled and considered in a manner described in the following section on the American bollworm.

Surveys of the course of oviposition, taken as described, supply quantitative data which are viewed with reference to the life of the host-plants.

Larval Populations.

It is necessary for various reasons to estimate closely the percentage survival of larvae resulting in crops where the numbers of eggs laid have been recorded. The survival varies considerably with the habit of growth of the plant and the constitution of the general insect community associated with the crop, particularly those members of it which are parasitic or predatory on bollworm. These are fostered to a variable extent by insects present other than bollworm.

The course of natural parasitism of larvae must be known, also the parasites concerned and the growth stages of the larvae in which parasitism occurs. This information, to be of real value, requires to be stated in relation to a known larval population, throughout an infestation. In both egg and larval parasite release experiments the authors consider that the larval population must be measured continuously and as accurately as possible. Unless this is done, it would appear impossible to assess the value of a parasite as so many other factors may intervene and contribute to erroneous conclusions.

In both routine and experimental field work bollworm larvae are recorded and collections made weekly in all crops throughout the year. The methods are as follows :—

The same number of plants is taken in each area as have been marked for egg counts. The egg record plants are not searched for larvae, as a rule, as this may, in fact frequently does, involve stripping off and examining all fruit, cutting open stems, etc. The plants taken, however, are always situated near to the plants marked for egg records so that the distribution is the same.

The growth stage of a larva is recorded when it is found. It is known (Dyar's Law, 1890) that the width of the head-capsule of a Lepidopterous larva does not alter within each instar. The widths of head-capsules in each instar of the two bollworms concerned have been determined here. In the case of the American bollworm our figures for these measurements agree closely with those published in America by Quaintance and Brues (1905). From these measurements numbered scales have been prepared on stiff pieces of celluloid. These are carried by observers in the field, and it is a simple matter to bring the head of a larva against the underside of the transparent celluloid and pass it along to see which measure the width of the head-capsule agrees with. The figures are entered on record sheets from which the larval population may be assessed according to instars. It is possible from growth development records, which are carried on continuously at the Cotton Station

throughout the climatic changes of the year, to estimate closely the date of the egg-laying from which a larva is derived. This information has been of particular value in egg-parasite release experiments at Barberton.

As a rule the larvae found on every fourth plant, only, are collected, the remainder being destroyed. To obviate losses due to cannibalism, the larvae when collected are placed in individual containers. Those at present in use are 28-gauge shot cartridge-cases which are carried in lots of 25 in belts made for the purpose. The cases are conveniently plugged with cotton-wool. These larvae are placed in individual cages at the laboratory and are observed daily for growth development, parasitism and pupation data.

In the summer season the larvae from routine collections are fed on food from plants of the same kind as those from which they were collected. In the winter, bean and pea plant matter, only, is available. The larval containers previously in use were of glass with ventilated tops. Under the system now in operation they are kept in individual cylindrical wire gauze cages, giving ample ventilation. These are of 1,000 mesh wire for the early instars, 800 mesh wire for the middle instars, and 100 mesh wire for large larvae. The cages are six inches long and one inch in diameter. One end is closed with a cork stopper through which a hole is bored. Through this a leaf or other plant portion may be inserted. The cork (with hole) end rests in a groove immediately over an opening in a sheet of galvanised iron which forms the cover of a water tank below. One end of the piece of plant material dips into the water in the tank. The upper end of the cage is closed with a cork stopper. For certain experimental work nutritive solutions may be placed in the tanks and caged seedlings grown in them.

The cages are used mainly for American bollworm. They are made in units holding 500 larvae. For each unit there is a duplicate. This is made ready with fresh food as required, and the larvae are transferred to their numbered cages. The unit from which they have been transferred is then cleaned and sterilised. The above procedure has been adopted with a view to reducing disease and digestive troubles to a minimum.

The treatment of larvae for pupation work is discussed later in connection with moth emergence data.

It has been possible, by adhering to a calendar of operations, to record bollworm material, as described, over the Cotton Station, Barberton and several farms in the district throughout the year, and identical measures are in operation at stations established in Natal and the Swaziland Protectorate. They have also been adopted by workers in Rhodesia on a closely co-ordinative basis.

INVESTIGATIONS ON THE AMERICAN BOLLWORM, *HELIOTHIS OBSOLETA*, FABR.

The Course of Oviposition on Rain-grown Crops.

Apart from some tobacco, cotton and maize have been the only rain-grown crops in growth on farms in the area for the period under record. Tobacco, where observed, has given negative returns in many cases, probably because of the practice of removing the upper portion of the stalk before flowering.

More recent information suggests that tobacco, particularly rain-grown tobacco, occupies an important place as a food-plant of the American bollworm. In addition to cotton and maize, the sunflower, groundnut and various bean crops grown on the Cotton Station have been examined.

The crops reported upon were not planted, as to date, with any consideration of their possible relation to bollworm attack. Recording commenced when crops were in an early stage of growth. Successive plantings of the same crop were observed.

In fig. 1 the course of oviposition on Farm 1 is illustrated. The only crops produced on this farm were cotton and maize. The cotton crops comprised two very healthy stands of plant or annual cotton and a first and a second year crop of ratooned cotton. There were four fields of maize which had been planted two or three weeks apart. The total acreages of maize and cotton were practically equal. Eggs of *H. obsoleta* were found first on the earliest crop of maize. At the time oviposition was first observed to occur on these maize plants, 10 per cent. of them had just

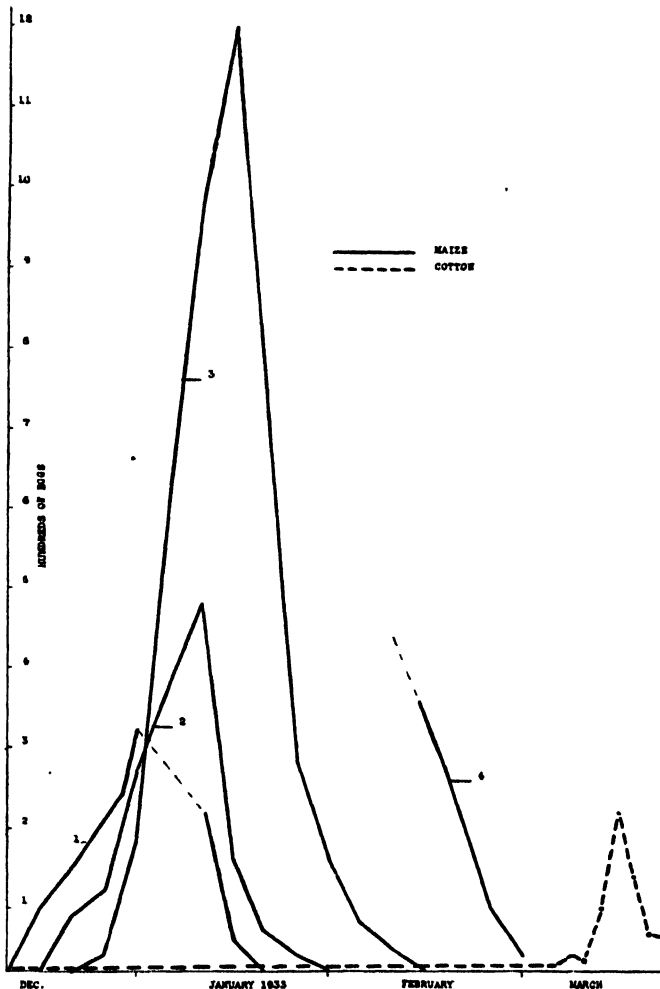


Fig. 1.—The course of oviposition by *H. obsoleta*, on cotton and maize on farm No. 1 (96 plants of each).

extruded the tip of the tassel or male inflorescence. The plant cotton at the time was flowering freely, and ratooned cotton bore fresh bolls and flowers in abundance. Cotton in this condition is considered to be highly attractive to *H. obsoleta*. Reference to diagram no. 1 will show, however, that all the oviposition occurred in successive waves on the successive maize crops. The laying on the third planting of maize (crop no. 3) was the heaviest recorded anywhere during this season. No *Heliothis* eggs were found on cotton on this farm until mid-March as the graph for cotton

depicts. At this time the ratooned cotton was bearing a ripe crop and the records apply to plant cotton only. This also, however, was carrying a few open bolls and was too far advanced towards ripening off to be damaged seriously by bollworm.

The course of oviposition on the Cotton Station for one season in respect of maize and cotton crops of different planting dates is illustrated in fig. 2, and furnishes also the oviposition data on sunflower and groundnut crops. In addition to these soya, lima and tepary beans (*Phaseolus acutifolius*) were examined.

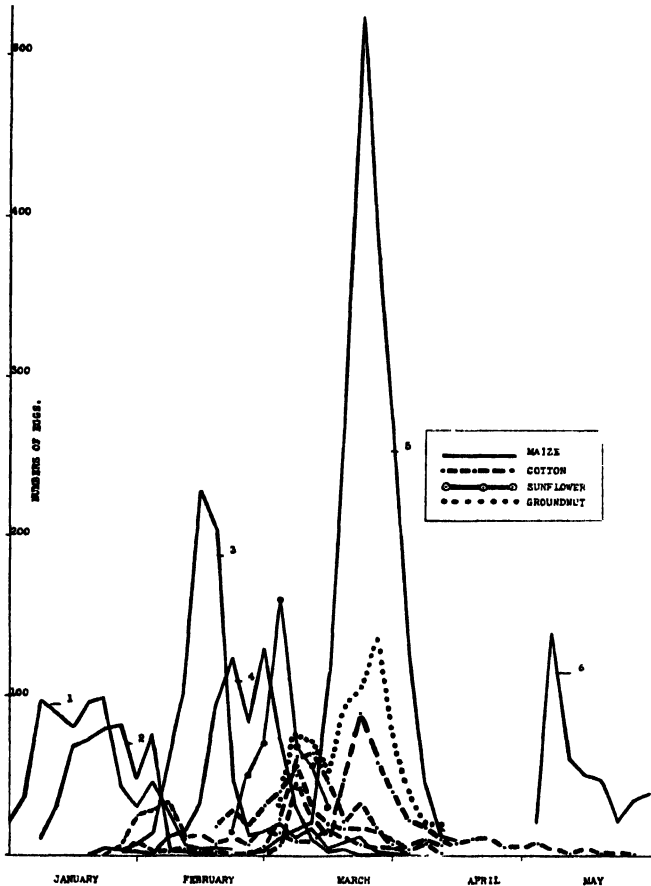


Fig. 2.—Oviposition by *H. obsoleta*, on cotton, maize, sunflower and groundnut crops, 1933 (96 plants of each). Cotton Station, Barberton.

On the Cotton Station the earliest crops of cotton and maize were planted over a month later than those referred to on Farm 1. The planting dates of maize were wider apart than in the first example. In these cases practically all the oviposition occurred on maize. There were three occasions when increased numbers of eggs were reported from cotton, as shown in fig. 2. The first two occasions coincide with periods between the falling off of oviposition on one maize crop and the occurrence of heavier egg-laying on the next, later, planting of maize. The third occasion happened near the end of the growing season on some very late planted cotton, which was then fresh and flowering, whereas all other crops, with the exception of one small field of maize, were drying off. In relation to the heavy laying on the

small field of maize referred to, crop no. 5, this was comparatively negligible. In the case of maize, eggs first appeared thereon, in any numbers, on the extrusion of tassels.

The oviposition on soya beans was associated with the period of bud and flower production only. Eggs were recorded on lima beans from the 28th January to the end of March. These were observed first simultaneously with the production of the earliest flowers and were not found when flowering ceased.

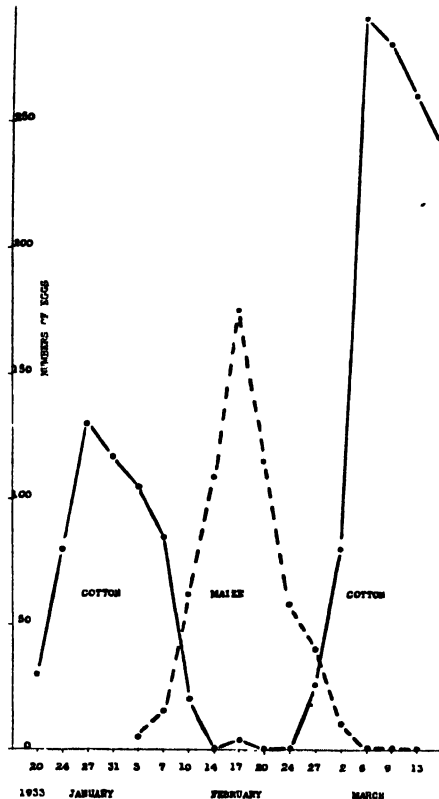


Fig. 3.—Oviposition on maize and cotton by *H. obsoleta*, on farm No. 2 (96 plants of each).

Fig. 3 depicts the course of oviposition found to occur on Farm 2. There was one planting of maize (40 acres) on this farm and one main field of cotton (23 acres). The maize crop was planted some weeks after cotton and experienced very difficult, low moisture conditions, in consequence of which growth was delayed and fruiting meagre. It may be seen from fig. 3 that considerable oviposition was recorded on cotton before eggs were found on maize, but that when eggs appeared on the maize plants, egg-laying on cotton ceased and was not resumed until that on maize fell off. Thereafter renewed oviposition was recorded on cotton. In this instance it was observed again that *Heliothis* commenced laying on maize simultaneously with the appearance of the tassels. Although the maize plants were very poorly grown they were not, apparently, unattractive to the bollworm moth. The maize and cotton lands were adjacent.

Fig. 4 illustrates the partial course of oviposition on Farm No. 3 where cotton alone was grown. In this case the crop was early and observations were not commenced in time to record an apparently heavy oviposition which had occurred as evidenced by the larval population found when recording began. Data on the

5th and 6th instar portions of the larval population are given in the diagram. The numbers found indicate relatively heavy egg-laying.

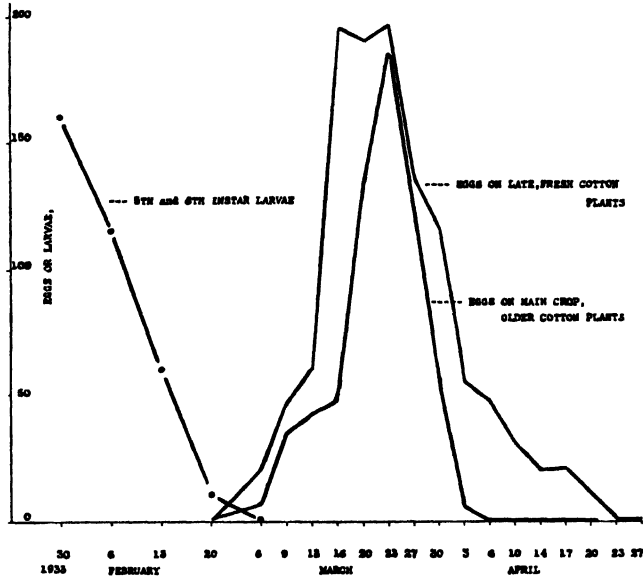


Fig. 4.—Oviposition on maize and cotton by *H. obsoleta* on farm No. 3 (96 plants of each).

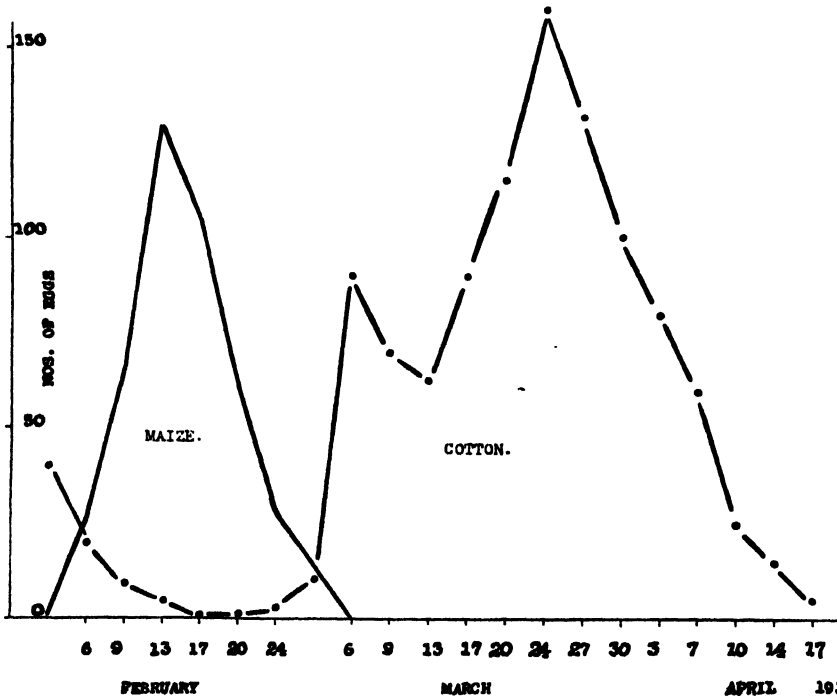


Fig. 5.—Oviposition on maize and cotton by *H. obsoleta*, on farm No. 4 (96 plants of each).

In this case the later oviposition on cotton was extensive over a period of six weeks which contrasts widely with the course of events on farms where maize crops were produced.

Fig. 5 provides a picture of the course of egg-laying on Farm no. 4. In this instance 20 rows only of maize had been planted three to four weeks after the main cotton crop. The rows of maize were situated alongside the cotton. Records were taken in the strip of maize plants and the cotton concurrently. While oviposition was in progress on the maize, eggs were not found on the adjacent cotton. Immediately oviposition on the maize plants fell off, eggs were recorded on cotton, and the subsequent course of oviposition there is shown in the diagram. In this instance also an early and heavy oviposition had occurred on cotton prior to the commencement of recording and before the maize plants were in tassel as numbers of larvae were feeding on the cotton when observers first entered the crop.

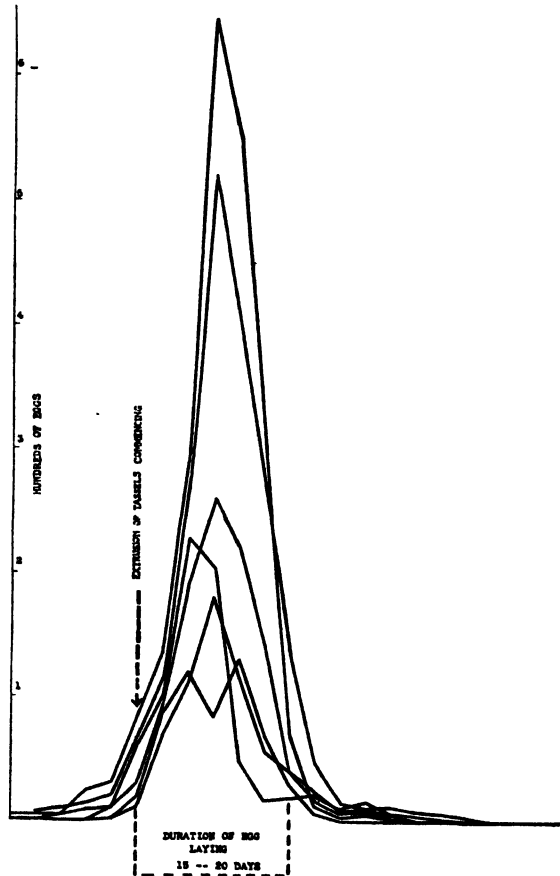


Fig. 6.—The course of oviposition by *H. obsoleta*, on six maize crops of widely differing planting dates and growth conditions.

On three other farms similar conditions were observed. If maize was present as well as cotton, *Heliothis* at some period in the season practically confined oviposition to maize. From growth records it was observed that a definite relationship appeared to exist between egg deposition on maize and certain conditions in the reproductive phase of this plant. This is referred to later.

Oviposition on cotton crops at the Cotton Station for the period under review was always very light. The egg-laying that did occur commenced in January on the earliest cotton coincidentally with the appearance of the first few flowers and

continued until April when the cotton plants began to ripen off. The period of time during which eggs were deposited on maize, however, was relatively short and markedly similar.

In fig. 6 are shown together the graphs of oviposition as recorded on six crops of maize of widely differing planting dates, varietal habit and growth conditions, ranging from December 1932 to October 1933. These are superimposed in the diagram. The data are all from twice-weekly records. It is clear from the diagram that the form of the graphs, apart from magnitude, is the same and the period of time during which eggs appeared in any quantity on maize plants was only 15–20 days. It may be remarked that at the commencement of this season moderately light egg-laying was observed upon young maize plants over a longer period. It is thought, however, in the light of present information that this was due to the absence of any food material, other than these young plants. At that time of year, irrigated crops in the Barberton District had ripened off and rain-grown crops were only in early stages of vegetative growth; consequently no alternative cultivated food-plants existed.

The typical course of oviposition on maize is apparently that shown in fig. 6.

The graph of oviposition on sunflower in fig. 2 is compiled from data taken on three plots of this crop planted at short intervals of time. The comparative stage of growth in each planting may be represented as follows: No. 1 crop was in full flower with well expanded heads when No. 2 crop showed a few open flowers, numbers of partially opened flowers and advanced buds, whereas No. 3 crop was in the stage of bearing many buds about to open. The oviposition graphs for each of these, which are not illustrated, overlap in a succession and reveal an individual course of egg-laying which definitely follows flower production on the three closely successive crops. Eggs were laid on the plants over a period of three weeks only.

Oviposition on groundnuts was observed to occur during the period of free flowering. It may be recalled that this also happened with lima beans.

Oviposition on Maize in relation to Flowering.

Frequent reference has been made to the coincidence between the appearance of eggs in numbers on maize and the production of the male inflorescence. The statement is made commonly in the literature that maize is a favoured food-plant of *Heliothis obsoleta*, and it is frequently stated or implied that the plant is most attractive to moths during the period of silking (female flower) production, the silks being extruded for a variable time after the appearance of tassels. According to Quaintance and Brues (1905), "corn is without doubt the preferred food of the bollworm and it is subject to attack from the time the plants are 12 to 18 inches high in the spring until late in the summer and fall, when the yellowing leaves and ripening ears are no longer attractive." Recently Ditman and Cory (1931) published data showing that, in their observations, 62 to 75 per cent. of the eggs were laid on silks. According to the evidence of our field surveys, maize is the favoured one of the food-plants observed in the rainy season, but the period in the life of the plant when attraction is exerted appeared to warrant investigation.

If maize is to be employed as a trap crop for *H. obsoleta*, as has been advised from time to time in different parts of the world, it is obviously important to know when the plant serves as an attractant to the best advantage, especially in view of the limited period over which attraction appears to be exerted, *vide* fig. 6.

In order to ascertain the relation between the growth-fruitlet condition of the plant and oviposition, the following preliminary investigation was conducted.

Ninety-six plants in a 2½ acre field of maize on the Cotton Station were taken for purposes of record according to Clapham's method of sampling. Observations

on these plants were made twice weekly as follows:—Height of plant and growth increment; leaf development; first appearance and development of tassels; and first appearance and development of silks.

The plants were 10 inches high when measurements commenced. Daily examinations for eggs were made. The course of oviposition on these plants is shown in fig. 7, where the graph for oviposition is plotted over data on the reproductive phase of development of the plants. These data are strictly comparable as to time of occurrence. The vertical bar chart in black represents tassel extrusion expressed, for each date of record, as the percentage of the plants, which had, up to that date, produced *visible* tassels. There is obviously a striking correlation between oviposition and tassellation in these data.

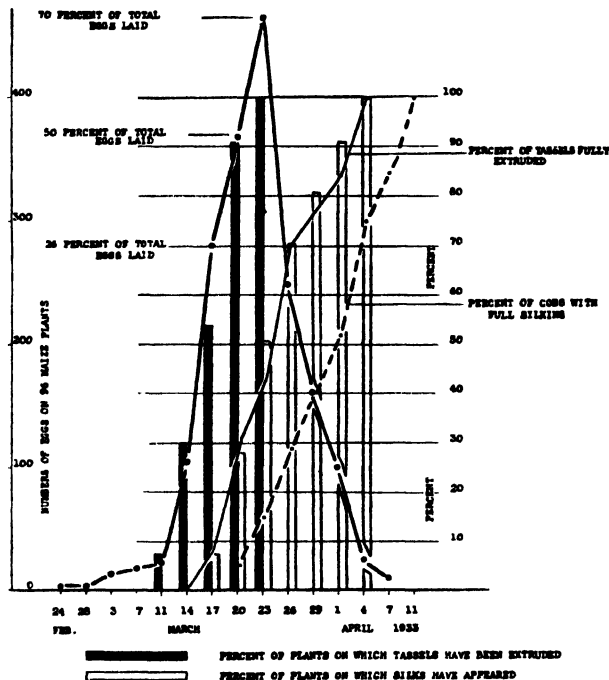


Fig. 7.—Oviposition by *H. obsoleta* on maize in relation to the reproductive phase of the plant.

Only a very few eggs were found before the first tassels appeared. Thereafter eggs became abundant, and the peak of the oviposition coincided with tassellation on all plants. Up to that time 70 per cent. of the total eggs laid had been recorded.

Silking is expressed, as for tassellation, in the vertical white bar chart. It may be seen from the diagram that silks were apparent on 50 per cent. of the plants at the period of *maximum* oviposition. The charts for both male and female flowers refer to young, developing structures only. Further data are given in the diagram which portray the percentage proportion of fully developed male and female structures in time relation to oviposition. From these it may be seen that oviposition was falling off by the time 60 per cent. of the tassels were fully extruded and before 30 per cent. of the plants bore silk in quantity. During the main period of abundant, fresh silk production, egg-laying did not occur.

These investigations agreed with the observations on many other maize crops, namely that oviposition commences, for all practical purposes, on the appearance of tassels and occupies the period of tassellation, eggs being laid mainly on leaves, stalks and the staminate flowers, a few only on silks.

Attention is also directed to fig. 2 where it may be seen that observations on maize crops nos. 3 and 4 were continued for a month after the typical course of egg-laying ceased without any recurrence of oviposition in quantity thereon.

This coincidence of insect-plant behaviour is being investigated at the present time with regard to certain chemical changes in the plant which are associated with the reproductive phase.

In all cases then, of the rain-grown crops observed, oviposition by *H. obsoleta* was closely associated with the flowering period, and the duration of oviposition varied according to the flowering habit of the food-plant. (See also data on winter-irrigated crops and citrus trees p. 361.)

Maize as a Trap Crop for *H. obsoleta*.

In view of the information obtained from the surveys it appears that *Heliothis* may be diverted from cotton to maize, provided that growth conditions are such as to permit tasselling on a series of maize crops. The maize concerned in these discussions was grown in a season, for the most part, of very difficult, low moisture conditions, and in several instances the crops were practical failures. In the latter half of the season, streak disease and rust were pronounced. Maize plants in this state were, however, oviposited on by *Heliothis*, and cotton plants near by in comparatively good health and fruiting freely escaped. One outstanding example of this is illustrated in fig. 3. The maize plants in this case were very poorly developed. Crop 6 in diagram no. 2 refers to the partial course of oviposition occurring on some very late planted maize. The growth of these plants was most irregular, ranging from plants a few inches in height to stunted plants tasselling prematurely. There were only a few of these latter. Observations were being taken at the time in a field of late cotton near by, as it was expected that increased egg-laying would be found there, after the maize represented by Crop 5, fig. 2, ceased to function as an attractant. The expected laying did not materialise, however, although it was known from records on pupae derived from 6th instar larvae collected in nos. 4 and 5 maize crops that numbers of moths would have emerged from those fields. On examination of the late, irregularly grown maize plants numbers of young larvae were found and egg-laying was in progress, of which we observed the latter end. It was noteworthy that the recorded oviposition was confined to a few flowering plants, a point which was remarked by a native enumerator. This meant of course that the oviposition was very concentrated and Crop 6 is not comparable with the others. These plants were in a field about 100 yards from the late cotton. The cotton was still flowering and fresh, but apparently *Heliothis* moths were more attracted to the maize, poor though the growth was.

The only evidence up to the present on the attraction exerted by a small lot of maize over a neighbouring, relatively large, field of cotton, is that obtained on Farm no. 4 (fig. 5). In this case 20 rows of maize about 140 yards in length extended alongside a field of cotton of about 20 acres. Oviposition occurred on these maize plants during the tasselling period to the exclusion of cotton.

Attention is now being directed to a study of the seasonal management of maize crops in relation to cotton and to the utilisation of maize in varying quantities for trap crop purposes.

Although the use of maize for trapping *Heliothis* in cotton growing areas has been advised in other countries, the practice has also been discountenanced (Entomological Conference of the Transcaucasian Cotton Committee 1929), because it

was held that *Heliothis* moths bred in maize would increase later infestations in cotton. Our evidence from larval surveys in both crops during 1933 and 1934 is that the percentage survival of American bollworm is greater in cotton than in maize. As will be discussed in the following section on the presence of *Heliothis* during the cool season on irrigated crops, the evidence is that moths bred there enter rain-grown crops that are present later on the same or contiguous farms. According to records, where no maize was in growth on farms, they oviposited on cotton. In these cases more moths could be bred from a similar population of eggs than resulted in the instances where maize was present in tassel and received the attention of moths. Where a timely succession of maize and possibly other rotation crops exists on the same farm and are laid on rather than on cotton, there would be, according to present data on larval survival, a general reduction of bollworm. This would apply of course if oviposition was divided between cotton and maize.

An argument against the above may be that *Heliothis* moths are stimulated by maize to lay more eggs thereon than they are stimulated to lay on cotton. At death there are still numbers of developed and undeveloped eggs in the ovarioles and oviduct of practically all female *Heliothis* moths, and these might be laid under special stimuli. Such stimuli may arise during the period of life of the maize plant which is associated with oviposition. We have no information, as yet, on this point. It is not known over what distance maize may attract moths. If maize is in growth on Farm B and not on Farm A a mile or two away, the maize grower may get moths that would otherwise have remained on Farm A. The occurrences reported are at present regarded as a diversion of moth activity, which, quite apart from the attraction to maize, probably meant reduced breeding of bollworm on farms where both cotton and maize were grown. In the above connection, attention should be given to later data on the activities of parasites and predators of *Heliothis* eggs and larvae in both crops.

In some areas during past seasons, American bollworm infestations in cotton have been exceptionally heavy, assuming at times "epidemic" proportions. As previously stated, the heaviest oviposition encountered since systematic recording began was that which is illustrated in Crop 3, fig. 1. It has been computed from general field data on survival of eggs and larvae that this would not mean a particularly heavy infestation of larvae on maize. It remains to be seen whether a crop of maize, especially a small area of it, in the right condition of growth, would be oviposited on rather than cotton when unusually large numbers of moths are present. Future co-ordinated survey work should soon provide information on this point.

Oviposition by *H. obsoleta* on winter-irrigated Crops and Citrus.

Rather more than 1,000 acres of vegetable crops are grown in the winter and spring under irrigation in the De Kaap Valley, where Barberton is situated. Within 40 to 50 miles of Barberton there are other valleys where considerable areas of crops are grown under irrigation. In addition it is estimated that there are some 8,000 acres of citrus orchards in the Barberton and contiguous districts.

Taylor has reported (1932) that American bollworm is found on the winter crops and citrus trees in the De Kaap Valley. Our attention was first directed to the incidence of the bollworm on these crops in 1930, when searching for eggs from which to procure the parasite *Trichogramma lutea*. It was observed then that they became extensively infested as the weather became warmer from September onwards. As a result of general observations in the winters of 1931 and 1932, it was concluded that very large numbers of the American bollworm are bred in irrigated crops before these draw to a close in November, and that moths would be emerging therefrom when rain-grown crops appear on the same and neighbouring farms, shortly afterwards. It appeared that the American bollworm which attacks cotton and other rain-grown crops might be derived mainly from these breeding-grounds, and it was decided to examine the situation in detail. Although the course of bollworm activity

on various hosts was observed closely late in the winters of 1931 and 1932 in these breeding areas, the observations did not include citrus orchards, nor were they, as experience showed, sufficiently frequent and comprehensive for ecological purposes. The methods of field survey, as described, are now being applied to a study of *Heliothis* in citrus orchards and vegetable crops.

It is convenient to discuss here the method of recording in citrus orchards. Those under observation are marked off into eight blocks containing 66 trees each and a sample of six record trees is taken at random in each of the blocks. The orchards consist mainly of Washington navel and Valencia orange trees, both of which have been examined, as follows :—

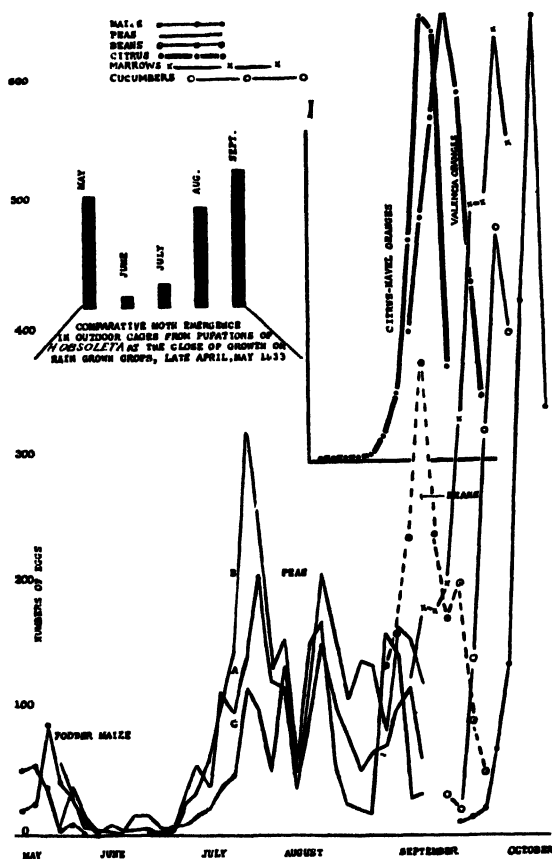


Fig. 8.—Oviposition by *H. obsoleta*, on irrigated citrus orchards and market-garden crops in the upper De Kaap Valley. Winter-Spring season, 1933.

Five observation points were marked at regular intervals round the periphery of a tree, the heights of points varying. A point consisted of a group of small branches bearing leaves as formed on the forked ends of a larger branch. A label was tied at the fork and observers were instructed to examine the leaves and flowers from the label outwards to the periphery. The surface area to be examined at each point was comparable to that of a well-grown soya bean plant. Points were labelled at intervals round the tree, as on windy nights oviposition might be greater on the sheltered side, and it also happens frequently that blossoming on one side of the tree

is heavier than elsewhere. The records for each observation point were entered separately. Winds were not experienced in the instances referred to, but more eggs were found on sections of the trees where blossoming was greatest.

The course of oviposition on vegetable crops and citrus trees in the winter season, 1933, is illustrated in fig. 8. The final rain-grown crops consisted of fodder maize on which eggs were laid in May and early June. For the following three months, field peas provided practically the sole host. The crops A, B and C in the diagram existed on different farms. The very marked similarity in the course of oviposition on these indicates two well defined flights of moths and a third less well defined. Reference is made to this in later discussions of moth emergence data. Egg-laying commenced on peas when flowering started and continued for $3\frac{1}{2}$ months on the same crops. Eggs were still being found in numbers on the peas when the plants became badly attacked by a powdery mildew, while still flowering and they were then taken out.

August plantings of beans, marrows, cucumbers and maize followed peas. Small areas of tomatoes were also set out. Oviposition occurred on each of these coincident with the appearance of flowers. As the season advanced, two or more plantings of the same crop were present and eggs were to be found in increasing abundance. The increased egg-laying is evident from the diagram. Data in the succeeding section on moth emergence in the winter serve to explain the increase in oviposition.

Fig. 8 illustrates egg-laying on one crop of each of those under observation. The data are from 96 record plants in all cases. The graphs are comparable for relative magnitude of oviposition with the exception of those for citrus in the upper right-hand corner of the diagram. Egg-laying on citrus trees did not occur until flowering commenced and endured for the period of flowering only, which lasted two weeks. The navel orange trees, as usually happens in this area, came into blossom about 10 days before the Valencias. Oviposition on the navel orange trees was falling off as that on the Valencias increased. The two graphs illustrate the events. Having regard for the very small fraction of the surface area of a tree examined, it was evident that enormous numbers of eggs were laid on these trees.

A somewhat similar course of events to that illustrated in the diagram occurred in all probability in crops and orchards over the whole of the De Kaap and neighbouring valleys during the period referred to.

Winter Crops and Orchards as Breeding-grounds for *H. obsoleta*.

In discussing this subject, consideration should be given to the part played by parasites and predators. Apart from the egg parasite, *Phanurus*, which at times is fairly abundant, these have been conspicuously absent throughout the greater portion of the cool season months. In consequence of the inconsiderable checks imposed, in the periods under record, by natural agencies for control, it may be expected that large numbers of larvae would proceed to pupation in vegetable crop lands in the spring and early summer (October, November and December), and that moths would be emerging from these lands when rain-grown crops were again in existence to furnish a continuation of host plants.

In 1933 oviposition on the citrus trees observed ended by the 7th October, the latest egg-laying being on Valencias. Larvae bred on these trees and pupating in October may be expected to give rise to moths late in November. It is possible that moths would oviposit on early summer crops as well as on vegetable crops still in growth. From information obtained in other years, however, it is known that the blossoming time of citrus varies considerably. In some years blossoming may not occur until late October. Moths derived from eggs laid on citrus then would be in flight at the end of December. Most of these moths would come from orchards of Valencia oranges, where the latest breeding of bollworm on citrus takes

place. We are indebted to officials at the Government Sub-Tropical Experiment Station, Nelspruit, Transvaal, for the information that there are approximately 800,000 citrus trees in this and neighbouring areas; of these practically 400,000 are Valencias. It is conceivable that circumstances may arise which cause citrus trees to blossom unusually late in a season favouring the early development of rain grown crops. The late emergence of moths from such extensive breeding areas could then occasion the "epidemic" infestations of American bollworm on cotton, previously referred to. Future survey work should afford exact information on this point.

Moth Emergence and Duration of the Pupal Period.

The following table gives the pupal periods recorded at Barberton in 1933. The most frequently occurring number of days' duration as pupae is given in each case.

TABLE I.
Pupal Periods.

Months in which moths emerged			Days as pupae	
January	...	...	15	
February	...	...	15	
March	...	...	17	
April	...	...	22	
May	...	...	28	
June	...	...	49	} Moths emerging from pupae formed in late April and May, from larvae bred on rain-grown crops at the close of the season.
July	...	...	52	
August	...	...	115	
September	...	...	138	
October	...	...	160	
August	...	...	66	} Moths emerging from pupae formed in June and July, from larvae bred on fodder maize and the earliest winter peas
September	...	...	80	
September	...	...	35	Moths emerging from pupae formed in August, from larvae bred in pea and vegetable crops.
October	...	...	23	Moths emerging from pupae formed in September and October, from larvae bred in vegetable crops and citrus orchards.

These data have been taken from the recorded emergence of 700 moths over the period concerned. For the months January to April inclusive, the records were obtained from pupae formed in an insectary by larvae collected in routine survey work. The duration of pupation in the summer months differed by no more than a day or two, whether larvae were bred on standing crops under cages and pupated in the soil or were bred on fresh food supplied in the insectary and pupated in test-tubes. With the approach of cool weather, however, the following methods were adopted in order to obtain data on material under natural conditions.

At the end of April late maize (fodder maize) was the main food-plant in fresh condition. Maize of this description was available on the Cotton Station. Two

to three suitable plants in this crop were enclosed in each of a number of cages. Fifth instar larvae collected from maize in weekly routine work were placed on the caged plants and fed there until they moulted into the 6th instar. They were then transferred to individual cylindrical cages made of wire gauze and open at the bottom. These cages are placed in the open in areas of soil enclosed within a frame of galvanised iron, 2 ft. 6 ins. square and 12 ins. deep. The frames, which are open at the bottom, are set in excavations 9 ins. deep and the space is filled with soil which has been heated sufficiently to destroy the insect life in it, particularly ants predatory on pupae. A trough 2½ ins. wide is provided around the top of each frame. This is kept filled with a solution which prevents the access of crawling insects. The upper half of a fresh maize cob was placed in each cage to provide food for the remainder of the larval life. A length of stout wire forced into the base of a cob served to maintain it upright and to raise it a few inches off the soil surface. This tended to insure that, on leaving the cob to pupate, a larva would enter the soil to do so and not form a pupa beneath a cob which rested on the soil surface. The larvae collected for pupation work off vegetable crops in the winter were fed for the remainder of the larval period on bean plant matter kept fresh in water containers in the cages. An attempt has been made to provide for a minimum interruption of feeding under natural conditions followed by natural pupation. Maximum and minimum soil temperatures are recorded in the enclosures at 2, 3 and 4 ins. depth, as referred to later in discussions on red bollworm work. Data on these temperatures for the past three years are given in fig. 12.

A large proportion of the larvae pupating late in March and April gave rise to moths in May after increased pupal periods of 22 to 28 days. These moths emerged at a time when the rain-grown crops in the district consisted of a few small areas of fodder maize and before irrigated crops were advanced beyond the seedling stage. Oviposition on fodder maize is attributed to this, last, main flight of moths at the close of the summer season. The remainder of the larva bred in late March and April, and most of those bred from them until the host crops ripened off entered pupal periods of increased and varying duration as indicated in Table I. The relative quantity of moth emergence from these pupae in each of the months, June to September inclusive, is illustrated in the bar chart included in fig. 8.

It may be stated that the larval material used throughout has been provided by the 5th instar portion of the larval collections taken weekly in all crops under survey. Variations in the larval populations in these crops were reflected in the samples drawn weekly; hence the course of pupation and moth emergence in cages at the Cotton Station is believed to follow, proportionally, the course of these events occurring elsewhere in the district, including the effects of parasitism, although it is recognised that soil differences and treatment would introduce errors.

According to records of oviposition on field crops, moth activity in June was at the lowest point for the year (fig. 8). It is customary to find that a few moths emerge, after more or less normal pupal periods for that time of year, from pupae of the final population of larvae on summer crops. Some emergence occurred in the cages during May and June of the past year from pupae formed within those months. The light oviposition observed on young crops of peas in June is attributed to a relatively small flight of moths emerging similarly elsewhere.

Break up of dormancy occurred in the cages amongst a portion of the overwintering pupae (April-May pupations) late in June and July. There were two distinct groups of emergences. This happened following a rain in both months, and it is highly probable that the break up of dormancy was induced by moisture conditions. Soil temperatures at the time were the lowest for the year, but maxima at 3 ins. soil depth were still between 70 and 77° and minima were commonly between 50 and 53°. The pupal development that occurred at the time resulted in two flights

of moths within a month of each other. As referred to previously, two periods of greatly increased oviposition were recorded simultaneously in July and August on pea crops on three farms (fig. 8). The oviposition was coincident with the two flights of moths represented by the emergences in cages. It is considered that these incidents offered further indications that field conditions are reflected in the cages at the Cotton Station.

It should be stated here that the areas bearing irrigated crops under observation in the instances reported had been out of crop for eight months, and it is doubtful that the lands would contain pupae to be acted upon by irrigation water. The bollworm activity in these crops at the time referred to would be due almost, if not entirely, to moths coming from lands that had borne summer crops.

To summarise the evidence from the pupation records and moth emergence it may be said that the moth population in irrigated crops and orchards from August to October would be contributed from pupae as follows:—

A. *August moths.*

1. Increased emergence from over-wintering pupae (*vide* comparative emergence chart in fig. 8).
2. Emergence, after pupal periods of 60–80 days, from pupations made in winter crop lands in June and July. These occurred with rising soil temperatures.

B. *September moths.*

1. Emergence as in A 1 continuing after pupal periods of 130 days.
2. Emergence as in A 2 continuing.
3. Additional emergence from winter crop lands after reduction of pupal periods to 35 days.

C. *October moths.*

1. Emergence as in B above.
2. Emergence from pupations in September and *within* the month of October.

The pupal period in October has been reduced to less than four weeks. The October moth population was comprised of moths emerging from pupae formed in the months April to October inclusive. The break up of dormancy of most of the overwintering pupae occurred before the end of September.

It would appear that, in areas where irrigated crops, citrus orchards and other cultivated host-plants upon which *Heliothis* breeds are not present, the moths in flight from overwintering pupae when rain-grown crops appear must be very few. Information on this subject will be of considerable value in studying the course of American bollworm infestations in dry farming areas in the Low Veld of South Africa and Rhodesia.

In districts where dry-farming only is undertaken, it is common to find that no vegetable, fruit and flower gardens exist during the dry season in which small numbers of *Heliothis* might breed. It is possible, however, that wild food-plants in the veld serve to supply food for *Heliothis* at this time of year. Investigations on the presence of these are being made as opportunity offers. It should be stated also that according to Cockerell and Felt there is evidence that *H. obsoleta* flies long distances in the United States of America.

Parasites recorded from *H. obsoleta*.

A list of insects observed to be parasitic on *H. obsoleta* is given below together with information on the stage of the host attacked.

The list includes parasites additional to those given by Taylor (1932) from records in South Africa.

Two other egg-parasites have been found on rare occasions. These have not been identified.

Parasite	Stage of Host attacked	Emerging from
HYMENOPTERA		
ICHNEUMONIDAE		
<i>Metopius discolor</i> , Tosq.	Larva	Pupa
BRACONIDAE		
<i>Microbracon brevicornis</i> , Wesm.	Larva	Larva
MYMARIDAE		
Unidentified sp.	Egg	Egg
TRICHOGRAMMATIDAE		
<i>Trichogramma lutea</i> , Gir	Egg	Egg
<i>Trichogramma</i> sp.	Egg	Egg
SCELIONIDAE		
<i>Phanurus</i> sp. n. (?)	Egg	Egg
DIPTERA		
TACHINIDAE		
<i>Sturmia inconspicua</i> , Mg.	Larva	Larva or pupa
<i>Gonia bimaculata</i> , Wd.	Larva	Larva
Unidentified sp.	Larva	Larva
BOMBYLIIDAE		
Unidentified sp.	Larva	Larva

Larval Parasites.

Systematic collections of larvae for the determination of parasitism have been made at Barberton during the past three years. In the summer season 1931-32, records were also made on larval parasitism at Magut, Natal, by P. A. Bowmaker, and in Swaziland by J. V. Lochrie, in collaboration with the authors. Serial collections of larvae were taken at points near Louis Trichardt in the northern Transvaal to ascertain the presence of parasites in 1931 and again in 1933. At these three points larvae were collected from cotton only. The parasites found to be present at Louis Trichardt and at Barberton are the same. *Sturmia* only was found in material submitted by Lochrie. The American bollworm infestation in Swaziland in 1932 was reported, however, to be very light. In the same year at Magut one main brood of American bollworm attacked cotton in March, and it was reported that 20-30 per cent. of the late instar larvae were parasitised. This was attributed to *Sturmia*.

In 1931 at Barberton collections of larvae were made in cotton at the Cotton Station only. On the Station, generally, American bollworm was not found, but a moderately heavy infestation was discovered in two fields of cotton at one end of the farm. One brood only occurred on this cotton, from which samples were taken. *Sturmia* and *Gonia bimaculata* were bred from these larvae, giving a 27 per cent. and a 2 per cent. parasitism respectively. The presence of *Sturmia* in the one brood of

Heliothis to the extent observed may be explained by the fact that it is also a parasite of other hosts, including red bollworm, which existed in the crop at the time. *Gonia* is a parasite of the cutworm, *Euxoa segetum*, Schiff. which was then present in the lands.

In 1932 observations were restricted to the Cotton Station. In this season larval collections were taken from all the host crops of *Heliothis*. The infestation was confined mainly to maize, of which there were four successive plantings made at intervals of 2-3 weeks. The late instars of the first generation of larvae on maize were parasitised extensively, 41 per cent. being assigned to *Sturmia* and 27 per cent. to a Bombyliid, of which this was our first record. The Bombyliid was not found in later broods on the other maize crops, and parasitism by *Sturmia* ranged only from 10-14 per cent. of these later larvae, being confined to the advanced stages of larval growth.

In 1933, with the inauguration of the field methods of survey, the course of larval parasitism has been observed on all the rain-grown and winter-irrigated crops surveyed in the district.

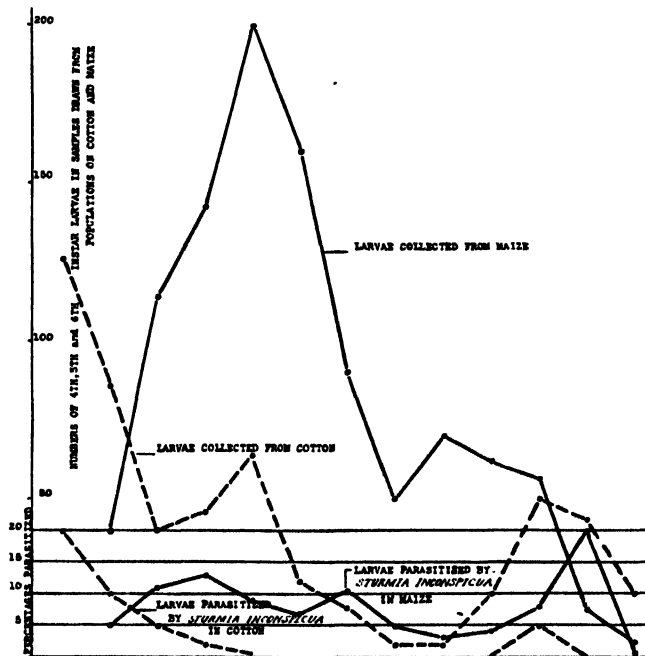


Fig. 9. 4th, 5th and 6th instar larvae of *H. obsoleta*, parasitised by *Sturmia inconspicua* on cotton and maize, January-April 1933.

The parasitism of larvae on rain-grown cotton and maize in 1933 is illustrated in fig. 9 together with graphs representing the larval populations in both crops over the months of January to April, inclusive. The graphs for population deal only with the 4th, 5th and 6th instar larvae, as we have not found parasitism to occur in instars earlier than the 4th (except very rarely in the 3rd instar). The data in fig. 9 are taken from all the larvae in these growth stages as collected in weekly samples from the two crops over a number of farms. The graphs show the fluctuating numbers of larvae on both crops and the percentages of these which were parasitised by *Sturmia* only, as the parasitism in both crops was due almost entirely to this fly. A Tachinid (unidentified species) occurred in cotton in very small numbers. *Metopius discolor* and the Bombyliid were the only other parasites found, and these rarely.

The maximum parasitism recorded on maize this year did not exceed 13 per cent. when larvae were plentiful, although *Sturmia* was present at all times.

It may be recalled that large numbers of larvae were found on early cotton crops in 1933, when observers first entered them for purposes of record. The larvae in the collections taken then were found to be parasitised to the extent of 20 per cent. by *Sturmia* and another unidentified Tachinid. In two succeeding samples from the diminishing numbers of this early brood, 14 per cent. and 8 per cent. respectively were parasitised by *Sturmia* only. In later broods of varying numbers on cotton, parasitism was never more than 5 per cent. and frequently non-existent, as shown in fig. 9. Larval parasites have not been found in the material collected off winter vegetables and orchard trees until the early summer, when a low parasitism due to *Sturmia* has been recorded.

Sturmia inconspicua is the only larval parasite of *H. obsoleta* that has attained any importance in our experience. It may emerge from the larva or the pupa. A parasitised larva feeds normally, practically speaking, until the parasite emerges and, consequently, the parasite plays little part in reducing the destructiveness of its host while an infestation is in progress. Furthermore the activities of *Sturmia* are divided amongst a number of hosts. In comparison with some other parts of the world it appears that insects parasitic on the larval stage of *H. obsoleta* are very few.

It is important to note that parasitism of the early growth stages of *H. obsoleta* has never been observed, here, by the present investigators. According to Quaintance and Brues (1905), Winburn and Painter (1932) and others, parasites which attack and destroy the young larvae extensively are present in America and elsewhere. Attention should now be given to the advisability of introducing parasites of *H. obsoleta* under authority from the Union Government.

Microbracon brevicornis, Wesm.

Taylor (1932) has reported the presence of *M. brevicornis* as a parasite of *H. obsoleta* in the Barberton district. He states that with one exception (marigolds), the parasite was not found attacking larvae in association with any species of plant other than *Antirrhinum*. In December 1932, however, it was observed (Uillyett) that larvae in a field of maize were parasitised by *M. brevicornis*, and this parasite was bred from 10 per cent. of the larvae in samples then taken.

Previous to this discovery by the junior author of the presence of the parasite in maize at Barberton, we had bred *M. brevicornis* in the laboratory for purposes of experimental releases in maize and cotton crops. At the commencement of this work the methods of rearing the parasite in cutworm larvae, as devised by Taylor, were used. In 1931, however, the junior author developed a technique for the production of the parasite in large numbers, utilising the larvae of *Plodia interpunctella*, Hb., as a host. His method, which has been described (1933), was employed in subsequent production.

Release experiments were undertaken in January and February 1932. It was observed then that although numbers of *H. obsoleta* were parasitised, the host larva decomposed so rapidly that the development of the parasite was prevented. Taylor (*loc. cit.*) has reported that large numbers of the cutworm host material employed by him decomposed rapidly in the laboratory during periods of high humidity in the summer months. We had observed on occasions that rapid decomposition occurred in larvae which had been paralysed by the parasite preparatory to oviposition thereon in breeding compartments. The parasites would paralyse and perhaps feed on a proportion of the larvae, but did not oviposit on them. It was found that these larvae were the first to undergo decomposition. The occasions were associated with periods of warm, moist weather.

As a preliminary to further release experiments in the summer it was decided to study the microclimatic conditions obtaining in (1) the burrow of *H. obsoleta* in

the tips of maize cobs and (2) a site within the leaf-sheath at the base of a maize cob where *H. obsoleta* occurs commonly. Parasitised larvae have been found in similar sites.

Atmospheric moisture was measured by hair hygrometers which were inserted into the positions, it being ascertained that a larva was present. The construction of the hygrometers was based on suggestions obtained from Buxton's valuable

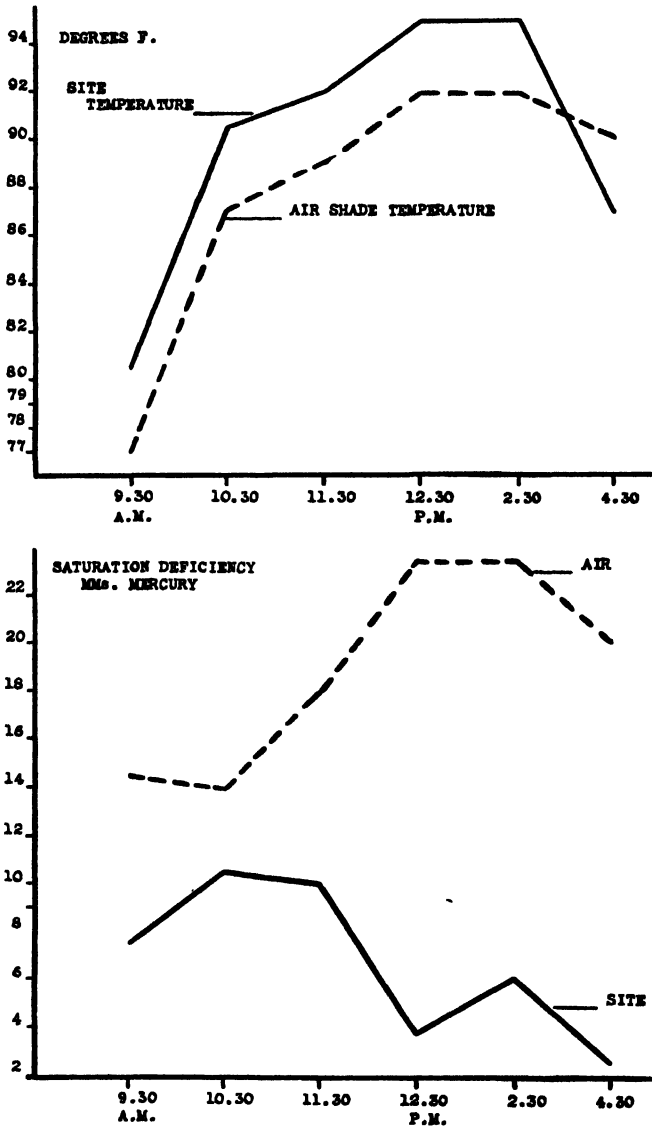


Fig. 10. Temperature and humidity in burrow of *H. obsoleta* larva in tip of maize cob.

paper (1931). These consisted of loose bundles of fine human hair contained within an open coil of thin aluminium wire about 1 inch long. The hair was treated with sulphuric ether to remove oil and fat and make it more sensitive to changes of atmospheric moisture. The hygrometers were calibrated over a series of solutions of sulphuric acid of known vapour pressure. In order to protect the apparatus

from becoming fouled with excrement and other matter, the whole was enclosed in a cylinder made of thin aluminium, in the walls of which lines of fine holes had been bored. The diameter of the cylinders used was 7 mm. For comparison of conditions in the sites and in the external atmosphere, hygrosopes were placed concurrently in a shaded position adjacent to the plants of record. The hygrosopes came into equilibrium with the moisture conditions in a few minutes.

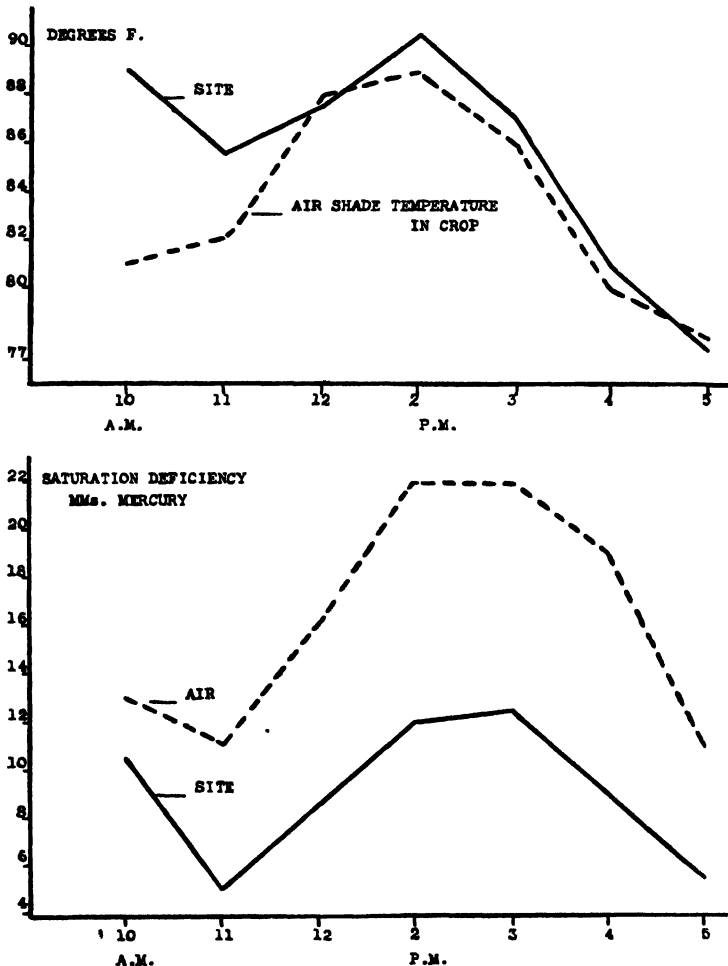


Fig. 11. Temperature and humidity in leaf-sheath of *H. obsoleta* larva at base of cob.

The temperatures where the larvae were feeding and air shade temperature were measured by a sensitive thermometer. Readings were taken at hourly intervals throughout the day. The hygrosopes when withdrawn were removed immediately from the protective cases and placed in weighing bottles, the saturation deficit being determined by referring differences in weight to charts prepared for each hygroscope when these were calibrated.

The data obtained from two sites are illustrated in figs. 10 and 11.

The temperature and moisture conditions found to obtain in the immediate environment of the feeding larvae were simulated closely in the laboratory and

parasitised larvae were exposed to them. The principal results may be summarised briefly as follows :—

1. At similar temperatures and high humidity, such as occurred in the sites, rapid decomposition of parasitised larvae ensued and no parasites developed.
2. At similar temperatures and over a range of low humidities no decomposition of parasitised larvae occurred and the larvae of the parasite developed normally.

TABLE II.

Weekly Records of Natural Parasitism of the Eggs of *H. obsoleta* by *Trichogramma lutea* and *Phanurus* sp. on Rain-grown Crops, December 1932–October 1933.

Date	Crop	No. of eggs observed	Per cent. parasitised by <i>T. lutea</i>	Per cent. parasitised by <i>Phanurus</i> sp.
Dec./32	Earliest maize	864	29.0	16.0
Jan. 6		768	13.5	—
13		820	8.0	—
23		410	7.0	—
Jan. 17	No. 2 crop maize	70	—	—
24		138	16.5	—
31		75	34.0	—
Feb. 7		34	44.0	—
14	No. 3 crop maize	14	14.0	—
Jan. 27		19	—	—
Feb. 3		38	—	—
10		162	7.5	—
17		351	13.4	—
24		62	13.0	—
Mar. 3		32	25.0	—
Feb. 7	No. 4 crop maize	26	—	—
14		45	—	—
20		219	3.2	—
28		213	5.0	—
Mar. 7		100	18.0	—
14	No. 5 crop maize	33	15.5	—
Mar. 3		26	—	—
10		68	8.0	—
20		758	6.5	—
28		820	6.2	—
Apl. 4	Cotton	254	1.2	—
11		54	—	—
Jan. 26	Cotton	64	—	—
Feb. 2		40	—	—
9		24	—	—
16		44	—	—
23		33	—	—
Mar. 2		56	—	—
9		160	—	—
16		398	3.0	—
23		378	15.3	2.0
30		176	17.0	—
Apl. 6		112	12.5	—
17		40	13.0	—

As a result of these observations, it was concluded that high humidity associated with high temperatures is probably a limiting factor to the useful exploitation of *M. brevicornis* in the field during the summer months at Barberton. The evidence

obtained was in accordance with observations on *H. obsoleta* parasitised in the field in the course of experimental releases and work on *M. brevicornis* in the summer season has been discontinued.

Egg Parasites.

It is hoped that work on *Trichogramma lutea*, to which attention has been given for four years, will form the subject of a separate publication.

The only other important egg parasite of *H. obsoleta* which we have encountered is a Scelionid, a species of *Phanurus*. This parasite has been bred from the egg of *H. obsoleta* collected in the cotton-growing areas of the Eastern Transvaal, Swaziland and Northern Natal. *Phanurus* has been found in abundance only in winter crops. Towards the end of the winter or dry season it has diminished in numbers, and thereafter until the following dry season it is seldom bred from the eggs of *H. obsoleta* collected off rain-grown crops.

Table II gives the percentages of *Heliothis* eggs found to be parasitised under natural conditions by *T. lutea* and *Phanurus* sp., from December 1932 to October 1933. It will be seen from the table that *Phanurus* was not bred from eggs in the summer, except on one occasion. In the latter months of the winter, however, it has been bred from upwards of 50 per cent. and more of the eggs taken for examination from a variety of vegetable crop plants. It has not been bred from eggs taken from citrus trees on any occasion, although on vegetable crops near by a 40-50 per cent. parasitism by *Phanurus* was in evidence at the same time.

The information obtained over three years suggests that *Trichogramma* supersedes *Phanurus* when numbers of the former appear in the late winter, owing partly no doubt to the shorter developmental period of *Trichogramma*, which is 7-9 days as compared with 12-14 days for *Phanurus*. One parasite emerges from each egg parasitised by *Phanurus*, whereas in the case of *T. lutea*, 2-3 parasites commonly emerge. This also may be advanced in explanation of the increase of *T. lutea* over the other parasite. Furthermore, as temperatures rise in the early summer, *Phanurus* appears to become less active.

It appears that *Phanurus* has a limited period of activity in the dry season when it has opportunity to breed extensively in the concentrated egg populations on vegetable crops. Unsuccessful attempts have been made to breed it in the laboratory.

Predators of *H. obsoleta*.

When taking daily records of American bollworm eggs on cotton plants it was observed that a certain proportion of the eggs became shrivelled and collapsed in a manner which suggested removal of the contents by some sucking insect. Observations proved that the responsible agent was an Anthocorid bug belonging to the genus *Orius*, very near *O. (Triphleps) insidiosus*, Say. The latter has been reported as predacious on the eggs and young larvae of *H. obsoleta* in America. A related species has been recorded similarly from Australia. During the summer, this Anthocorid is abundant on rain-grown crops and especially so on cotton and maize, where in our experience it has destroyed 40 per cent. of the eggs. In the winter season, it is difficult to find on the irrigated crops.

Ants observed to be predacious on the bollworm are common in both maize and cotton fields, but are somewhat more numerous in the former, judging from a preliminary census of colonies taken in 1933. The majority of colonies were those of species of *Pheidole*. Ants are among the predators of chief importance here, and investigations of their soil and host relationships form an important part of bollworm surveys in Africa. Such work is now in progress.

INVESTIGATIONS ON THE RED BOLLWORM, *DIPAROPSIS CASTANEA*, HMPSEN.

Very little red bollworm has occurred actually at the Cotton Station, Barberton, since the season 1926-27. Records of the red bollworm situation on farms in the neighbourhood of the Station were not taken prior to 1930, but it is known that severe attacks were experienced from time to time on various farms in the earlier years of cotton growing. Since 1929-30, only light red bollworm damage has been recorded or reported in the De Kaap Valley. On the other hand records taken in 1930-31 and 1931-32 on a large cotton estate situated some 100 miles east of Barberton showed red bollworm to be particularly numerous and destructive there. At certain points in the Northern Transvaal it has been recorded as abundant in successive seasons until 1930-31. Cotton was not planted there in the following year, with a view to observing the value of putting land out of cotton for a year as a measure for reducing infestation by it. This is discussed later.

In the years 1925-29, the senior author observed annually heavy attacks of this bollworm in ratooned and plant cotton in Zululand, so much so that it was regarded as the pest of major importance. The infestations there in later years have been much reduced. The course of red bollworm behaviour as reported from Swaziland over a period of years appears to have been much like that in Zululand.

According to reports from a district (Acornhoek) from which lies over hilly country northwards of Barberton, the red bollworm has attacked cotton severely every season. *D. castanea* was also reported from the Cotton Station, Gatooma, Southern Rhodesia, in 1930-31, this being its first observed appearance there. In the succeeding season a prolonged and moderately severe attack was experienced.

Under the system of co-ordinated cotton pest surveys now undertaken in Southern Africa, the actual status of the pest and the course of infestations in different areas will be made known, and it is expected that information will be forthcoming on the causes of the disparity in the incidence of this bollworm at various places. Later discussion on recording and investigational work carried out from Barberton make reference to various factors which have bearing on this point.

Owing to the scarcity of this moth at Barberton, much of the field work referred to below has been carried out at the Premier Cotton Estates in Portuguese East Africa, where the authors had exceptional facilities for arranging and directing investigations.

Moth Emergence from over-wintering Pupae.

Towards the close of the cotton-growing season, most mature larvae normally enter a lengthened pupal period. The inception and duration of this depend very considerably upon the temperature and moisture conditions of the season drawing to a close, as well as those of the succeeding winter months. Warmth and moisture in some years may permit of the growth of cotton well into otherwise dry mid-winter conditions. On these occasions, bollworm activity is prolonged and the length of the winter pupal period of a large proportion of the bollworm is reduced. According to laboratory evidence the break up of dormancy occurs when sufficiently warm conditions are present, development being accelerated in the presence of moisture.

There is evidence that the winter behaviour of the pupa varies greatly in the different cotton-growing areas of the country from season to season. These variations are ascribed to climatic influences, and it is important to know what the variations in this respect are, particularly in the off-season of cotton-growing, because the time and manner of the disposal of the season's plant cotton, ratooning practices and tillage operations are directly concerned. In this connection attention is directed to later discussion of the course of infestation on ratooned and plant cotton, where an example is given of a situation developed under favourable climatic conditions.

The time and quantity of moth emergence from over-wintering pupae have been studied at Barberton during the past three years. This has been done by observing the course of oviposition on ratooned cotton and recording moth emergence in outdoor cages in which pupae have been placed towards the close of the previous season. The cotton was ratooned soon after picking was completed, and the new vegetative and fruiting growth resulting in the winter months was observed for the presence of eggs. Eggs were sought for weekly and, latterly, twice a week over a sample of marked plants.

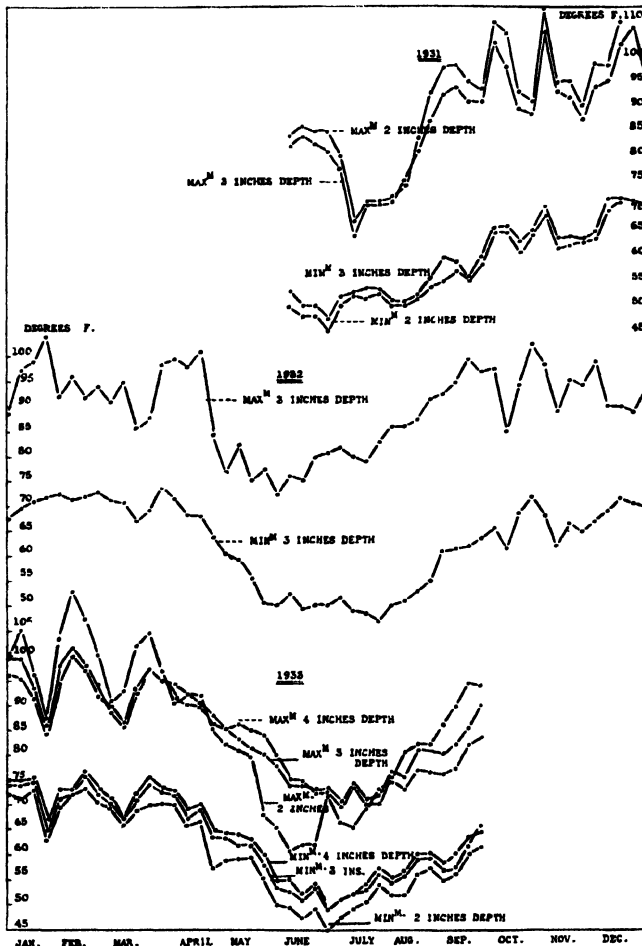


Fig. 12. Soil temperatures—weekly means in pupation cages of American and Red Bollworms.

The pupae for cage work were obtained from mature larvae collected from cotton towards the close of the growing season. The larvae pupated in the insectary, and the pupae were transferred to outdoor cages in which they were inserted at depths corresponding to conditions found to obtain in cotton lands at the time. The cages used are identical with the enclosed areas referred to in discussing the pupation of American bollworm, except that they are covered with wire netting tops.

In one of the cages three narrow maximum and minimum thermometers of the "Six's" type are placed in metal tubes. The thermometers are inserted slantwise,

and they enable soil temperatures to be taken at 2, 3 and 4 inches. The weekly means of the temperatures recorded in these cages for the last three years are given in the form of graphs in fig. 12. Moth emergence in the winter commences in August when soil temperatures rise. Soil for moisture determinations may be taken as required from one of the cages.

The soil in cages containing red bollworm pupae is turned with a spade when the cotton lands are ploughed and is otherwise treated with hand implements most appropriate for simulating, in due time, the various tillage operations which occur. The cages are also used to study the pupal periods during the growing season, and in order to simulate field conditions more closely, cotton is planted in rows alongside them. Moth emergence in these cages appears to follow closely occurrences in the field as evidenced by the course of oviposition on cotton. The main information obtained from these data for the years 1930-33 is that a small proportion of the moths are in flight during the months of August and September, that emergence becomes increasingly greater from October onwards, and that by the end of December 90 per cent. and more of the total emergence has taken place. Emergence to this extent occurs before plant cotton, in most seasons, has advanced beyond the stage of early bud formation.

It should be stated here that moths have not emerged from more than 15 per cent. of the over-wintering pupae inserted in cages. On later examinations most of the remaining pupae have always been found in a shrunken condition and covered with mould. Over-wintering pupae excavated in cotton lands are also commonly found to be like this. It is not infrequent to find 75 per cent. of the pupae in this condition. Parasitism, almost entirely due to *Sturmia inconspicua*, has accounted for 2-8 per cent. only of over-wintering pupae.

Utilisation of Trap Areas of Ratooned Cotton.

Data on the emergence of moths from over-wintering pupae, which the senior author obtained some years ago in Natal, suggested that most of the moths arising from these pupae were in flight by the end of December. The emergence behaviour observed at Barberton is in conformity with this earlier information.

The possibilities of utilising small areas of ratooned cotton as traps for the red bollworm moths emerging in the spring months have been discussed in previous publications.* It was considered that the presence of trap cotton in fruit would serve to attract the moths as they emerged, particularly those in flight shortly before plant cotton was again present and bearing buds. Although moths emerging in the winter months might be regarded as innocuous in the absence of host-plants, this does not apply to all moths emerging 3-4 weeks before plant cotton provides a host, as according to our observations, female moths caged with growing cotton plants may live and oviposit for periods up to 3 weeks.

The main emergence of moths has occurred in the months of November and December. In some seasons plant cotton has been well advanced in budding, even flowering, then. Concurrent egg records on trap plants and the plant cotton on these occasions showed that a great preponderance of the oviposition occurred on the large fruiting trap plants. This persisted until the plant cotton was bearing numbers of early flowers. Following the investigations on this point, it was determined from oviposition records and measurements of plants in fields of well-grown cotton, variable as to size of plant, that the egg laying on the large fruiting plants was constantly very much the heaviest. These observations in conjunction with the data on moth emergence from over-wintering pupae indicate that areas of well-grown trap cotton are of value in attracting thereto numbers of red bollworm moths, which otherwise may be expected to oviposit on young plant cotton.

* Reports from Experiment Stations, Empire Cotton Growing Corporation, 1927 *et seq.*

Unless the traps themselves are to become a breeding area, the fruit containing larvae must be removed before the larvae attain maturity and pupate. It is in this connection that the following objections must be lodged against the practical utilisation of the trapping method :—

In order to provide the trap, plants must be ratooned or allowed to stand over after picking is completed. Whether ratooned or stand-over, fruit will, in all probability, be in evidence on the plants some time in the winter months. Unless this is removed and destroyed at appropriate times after oviposition commences in the winter months, larvae will proceed to pupation. According to recent records the pupal periods of these are frequently of sufficient duration to mean that moths may not emerge until January, *i.e.*, after the trap has ceased to function as such. Formerly it was thought that pupae formed from the early larvae on trap plants would all give rise to moths before plant cotton was in bud.

Recent records have shown that the survival of red bollworm larvae in the dry season months is much higher than it is in the summer months, owing no doubt to the practical absence of natural agencies serving to reduce their numbers. It may be expected in consequence of this that a relatively large proportion will pupate. The accumulated pupae formed over August and September in a warm winter season might well give rise to as many or more moths than would emerge in cotton lands from the small proportion of over-wintering pupae that appears to survive.

Prior to the recent adoption of more frequent examinations, the view was held that the numbers of larvae bred in trap areas in mid-winter were negligibly few. This is found not to be so, and fruit must be collected and destroyed every 3–4 weeks after egg-laying commences. This involves constant observation to determine when egg-laying does begin. It is doubtful if the necessary measures would be taken in general practice by cotton farmers. If one or two collections were overlooked, the result might well be a very appreciable addition to the moths emerging when plant cotton is in growth.

The trapping method is considered to offer a valuable means of reducing red bollworm, and in certain instances no doubt it will be employed with due precaution ; but it should be discouraged for general use.

The Course of Infestation on Ratooned and Plant Cotton.

Cotton is usually ratooned in the winter. After being cut back, the plants still carry a few leaves and flower buds ; bolls also may be found. Even in very dry winters, a fresh growth of leaves appears on the cut stems a few weeks after the ratooning takes place. It is common to find that plants ratooned in July are flowering five weeks later. These provide abundant food-plants for red bollworm moths emerging in the winter, increasingly so as temperatures rise. Extensive breeding can take place in the fields of ratooned cotton before the season's plant cotton is in growth.

According to records, unless the infestation is particularly severe, the bollworm is confined mainly to the ratooned plants until the plant cotton becomes well grown and bears abundant fruit. This probably occurs about the end of January. Thereafter, as would be expected, the plant cotton may become heavily infested. This was a common occurrence in previous years when larger acreages of cotton were grown and ratooning was widely practised. Although, in many instances the ratooned plants were pastured by cattle during the winter or cut back again in the spring, considerable breeding occurred, and the high percentage survival of larvae at this time of year greatly enhanced the resulting moth population. It was under these circumstances that severe red bollworm attacks were experienced in former years.

The incidence of red bollworm was recorded continuously for over a year in one area, where it has been particularly destructive. Oviposition records commenced in August 1931 on ratooned cotton. This was heavily infested before plant cotton

TABLE III.

Oviposition by *D. castanea* on successive crops of Ratooned and Plant Cotton on the same Farm.

Date	Ratooned Cotton No. of eggs on 100 plants— weekly records	Early Plant Cotton Eggs on 100 plants ---weekly records	Late Plant Cotton Eggs on 100 plants ---weekly records
August, 1931	16		
	48		
September	150		
	106		
	138		
October	200		
	264		
	258		
	368		
November	388		
	290		
	428		
	568		
December	644		
	376		
	482		
	523		
January 1932	426		
	392		
	212		
	96	42	
	101	40	
February	56	133	
	81	119	
	60	160	
	34	240	
March	47	420	
		320	
		400	
April		480	
		400	
		600	
		900	
		580	141
May		420	184
		310	203
		200	300
		80	420
June		39	440
			500
			690
			1,000
July			1,150
			1,412
			810

Oviposition commenced again on ratooned cotton the following August and September.

was in evidence. A portion of the new season's crop was planted in November and December and a portion very late. The "normal" crop was not oviposited on to any extent until early February. At this time, egg-laying on the ratooned plants decreased and moth activity was diverted to plant cotton increasingly as the ratoons approached maturity. The subsequent infestation in the "normal" plant cotton was most extensive and destructive. The late cotton made poor growth in the summer and ordinarily would have been cut out or ratooned. In the early winter, however, rain fell, and as the weather remained warm, good growth resulted. This cotton then became so heavily infested with red bollworm that the crop was a total loss and the plants were ratooned, as well as a portion of the earlier crop. These again served as hosts as soon as fruit was produced to supply food for larvae. Table III gives the data from these records. In this area, where ratooning is the usual practice, red bollworm is a determining factor.

The presence of ratooned cotton in areas where moths emerge in the winter months affords unlimited opportunities for the breeding of red bollworm, and a good deal of the variation in the incidence of this bollworm must be attributed to the varying extent to which ratooning is practised.

In the absence of ratooned cotton, or other food-plants in quantity, it might be expected that, in a season of late planting, the cotton would largely escape attack by red bollworm. In reviewing the circumstances of the past few seasons, two facts merit consideration in the above connection. The first is that planting has been unusually late in some seasons of recent years. In these instances cotton was not planted in many places until January, which is one to two months later than is usual. The second point to be noted is that moth emergence in the caged enclosures at Barberton occurred as usual, whether conditions permitted the planting and growth of cotton or not. As the majority of the moths from over-wintering pupae are in flight before the end of December, it is considered that the late seasons experienced afford one explanation of the reduction in red bollworm. Together with this the area of ratooned cotton, which serves as a winter-spring breeding-ground, has been greatly reduced.

Experiment at Una Farm, Louis Trichardt, Northern Transvaal.

There are only three known wild food-plants of *D. castanea*, namely—wild cotton, *Cienfugosia hildebrandtii* (Parsons, 1927) and *Hibiscus calycinus*. *D. castanea* has been found on *H. calycinus* on one occasion only (Parsons, 1927). *C. hildebrandtii* is the main food-plant of which we have knowledge. This has not been observed in the Zoutpansberg region near Una Farm. Wild cotton is, however, present on the Northern side of the Zoutpansberg range some 30 miles from the farm.

It is considered that the initial infestation of red bollworm in cotton is light in areas relatively remote from natural breeding-grounds. The pest on becoming established in cotton on a farm well removed from wild hosts multiplies on the farm under such checks as may be imposed by natural agencies and farming operations. Una Farm appeared to represent an instance of this nature.

Prior to 1931 cotton on Una Farm was severely attacked by red bollworm. The lands were put out of all cotton from June or July 1931, to November 1932. The actual period from cutting out to the presence of fruiting cotton again would be about 18 months. The crops of the following season were practically free from red bollworm for the first time in several years.

SUMMARY.

Methods have been devised and applied to an intensive study of the course of bollworm activity on numerous rain-grown and irrigated crops. These were developed in the first instance to enable accumulation of data considered essential for evaluating the usefulness of certain egg and larval parasites when released experimentally.

and they have now been extended to the point of providing continuous, quantitative data on bollworm-food-plant relations. This work has been placed on a routine basis. The information that is supplied comprises :—

1. The course of oviposition in point of duration, magnitude and time of occurrence in the life of a host crop. This serves well to indicate the true course of moth activity on different food-plants, the relative attractiveness of these and to reveal if such matters are maintained under different conditions and bear definable relations to growth stages of a food-plant.
2. The identity and activity of egg and larval parasites under natural conditions.
3. The identity and activity of insects predatory on the eggs and larvae, as occurring in the varied insect communities associated with different crops.
4. Comparative mortality of larvae in the different crops where oviposition has been recorded.

Continuous records of egg-laying by the American bollworm, *H. obsoleta*, F., have been taken at the Cotton Station, Barberton and on several farms in the neighbourhood. Cotton and maize were the principal crops, but the surveys included a number of other food-plants. Egg-laying was found to be very closely associated with the period of bud and flower production, and its duration on different hosts thus varies according to the flowering habit.

In the case of maize, egg-laying in quantity commences when the tassels (staminate flowers) are extruding, and the peak of the oviposition is passed before silks (pistillate flowers) are abundant. This is at variance with the generally accepted view that the plant is most heavily oviposited upon during the silking period. The typical course of oviposition on maize here lasts for two to three weeks only.

Numerous instances were observed where oviposition by *Heliothis* occurred on maize in tassel to the practical exclusion of neighbouring cotton in freely fruiting and healthy condition, and the possibilities of exploiting this relationship are discussed.

As regards winter-irrigated vegetable crops and citrus orchards, data are given showing that the American Bollworm breeds extensively in these crops, particularly so a month or two prior to the appearance of rain-grown cotton, maize and tobacco.

The irrigated crops in the Barberton and contiguous districts are regarded as a main source from whence bollworm on cotton is derived. Citrus orchards of which there are relatively large acreages may be of particular importance in this regard.

The methods of obtaining information on the course of moth emergence are described. Data are given that explain the course of moth activity in winter crops and indicate when moths enter rain crops from winter breeding areas.

The only larval parasite of importance under natural conditions is *Sturmia inconspicua*, but this fly does not parasitise young larvae. There is a scarcity of insects parasitic on American bollworm larvae, and the question of importing them should be considered. Breeding and experimental releases of a larval parasite, *Microbracon brevicornis*, are discussed.

Two important egg parasites are a species of *Phanurus* and *Trichogramma lutea*.

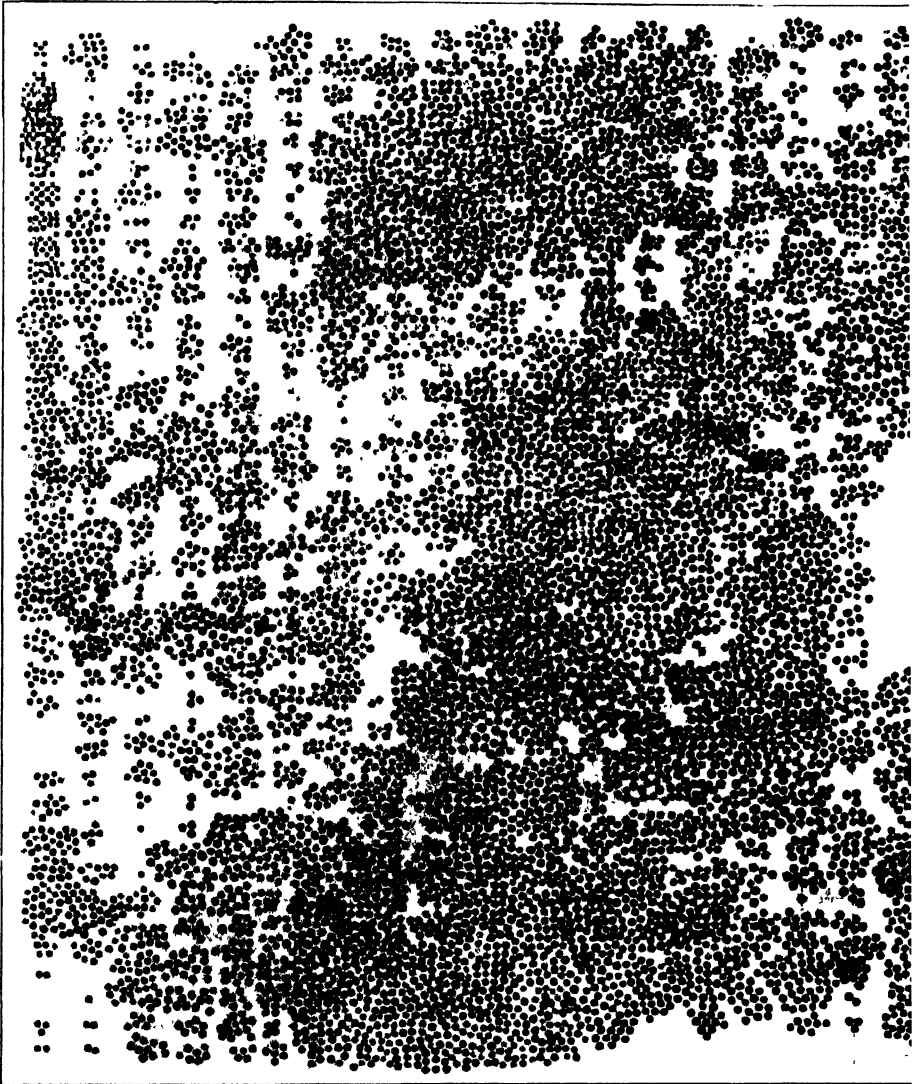
An Anthocorid bug, *Orius* sp., destroys large numbers of bollworm eggs and probably also young larvae, and this insect and certain species of ants are the most important agents in natural control.

As regards the red bollworm, *Diparopsis castanea*, Hmps., it is concluded that the use of trap crops should be discouraged for general adoption as a means of controlling

it owing to the danger, through inattention to the trap crops, of breeding this bollworm in them. Its incidence in former years is briefly reviewed. Of late years the annual infestation has diminished greatly in some districts but not in others. The variations in this regard are attributed mainly to the presence or otherwise of ratooned cotton, particularly in mild winters and to seasons of very late planting.

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Oviposition by *Heliothis obsoleta* in a fifteen acre field of maize showing variation in density of egg population. Target diagram constructed from records of eggs found on 16 sample plants in each of 50 quarter acre blocks.

PRELIMINARY OBSERVATIONS ON COTTON STAINERS AND INTERNAL BOLL DISEASE OF COTTON IN S. AFRICA.

By E. O. PEARSON, B.A.

Empire Cotton Growing Corporation, Barberton.

(PLATES XII, XIII.)

Introduction.

Investigations on this problem have been in progress at Barberton since the season 1931–1932. During that season and the one following, Mr. F. S. Parsons carried out observations on the migration of stainers (*Dysdercus* spp.) to cotton and the damage resulting from that migration, on some of the wild food-plants of the stainer, and on possible methods of trapping the stainer in the crop. Since November 1931, the writer has carried on whole time work on the problem. The present paper thus covers two seasons of intensive work in addition to the observations mentioned above.

Within the comparatively short time that continuous work has been in progress, little advance has been made beyond the stage at which it is possible to state the real nature of the problem, as it affects cotton growing in the Low Veld areas of South Africa, and to indicate the main lines to be followed. The present paper is mainly a record of preliminary and qualitative observations, and any conclusions drawn must be tempered by experience.

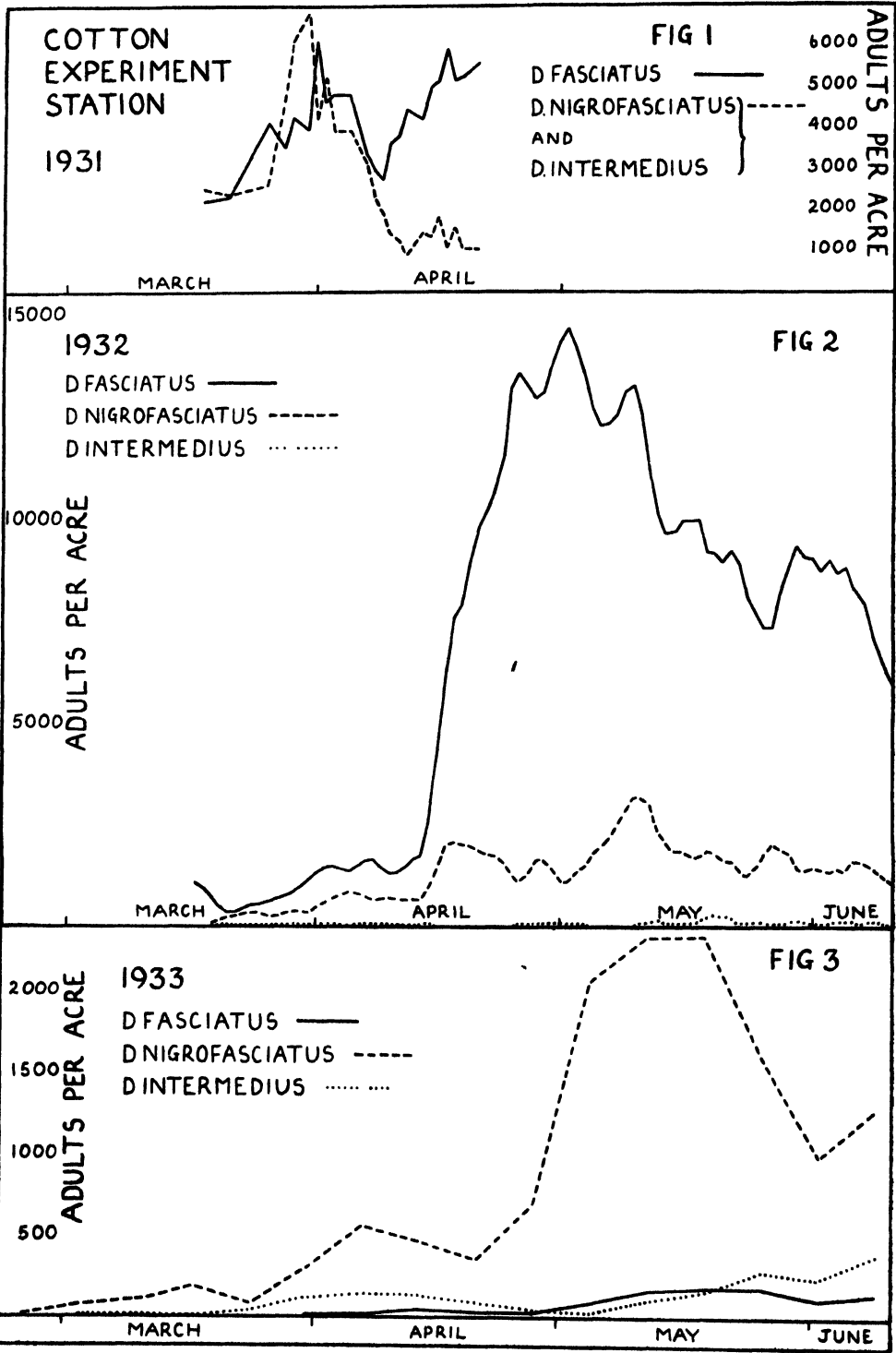
The writer is indebted to Mr. Parsons for permission to include some of the observations which were made by him prior to November 1931 and for his assistance and advice subsequent to that date; to Messrs. J. V. Lochrie and P. A. Bowmaker, of the Empire Cotton Growing Corporation's Experiment Stations at Bremersdorp, Swaziland and Magut, Natal, respectively, and to Mr. J. D. Inglis, of Lismore, Swaziland, for their co-operation in taking stainer records in the 1933 season; and to Mr. O. V. S. Heath, of this Station, for his assistance and suggestions with regard to the planning and statistical analysis of the method of stainer recording used in 1933.

Population Records in the Crop.

Stainer counts were first started in 1931, and in that and the following year were confined to the Cotton Experiment Station, Barberton. The experience gained in these two years has shown the necessity for a uniform system of recording the infestation in each distinct cotton-growing area and has enabled methods to be evolved for this purpose.

The different methods used in taking counts in the three seasons under review render the results not strictly comparable, but the seasons have been so obviously diverse, in respect of the stainer infestation, that some rough estimate of the differences of population in the different seasons may be obtained, whilst in any case the proportions of the different species of *Dysdercus* occurring are independent, to a very great extent, of the method of counting.

1931.—The object of taking counts this season was to discover the numbers and species involved in the initial migration to the crop. Counts were therefore performed daily by natives collecting all the adult stainers on 60 plants on a diagonal across each of the nine earliest fields of plant cotton. This gave rather less than a 1 per cent. sample, figures per acre being obtained by multiplying by the appropriate factor for plants per acre. The area on which counts were made constituted about one-third of the total area of cotton on the Station. It was assumed that the bulk of the migrant



population would settle in these fields. Had counts been taken over the whole area of cotton, it is probable that the population figures would have been only very slightly larger than those actually obtained ; hence in comparing figures for migrant population per acre *over the whole farm* in 1932 and 1933 with those in 1931, it is necessary to take roughly one-third of the 1931 figures. Furthermore, since by mid-April the earliest fields were decreasing in attractiveness whilst the later fields were opening out their main crop, the fact that the peak of the F_1 , or first generation bred in the crop, in the curve for 1931 is lower than the peak of the migration is explained by the shift of the newly moulted F_1 adults to the later opening fields. This is substantiated by the fact that the adult population in these later fields is known to have increased greatly about that time without any previous breeding in the fields to account for it. A migration from early to late fields must therefore have taken place.

Fig. 1 shows the course of the infestation. It will be seen that the migrant population consisted of *D. fasciatus* and *D. nigrofasciatus* in approximately equal numbers appearing almost simultaneously. At this time the distinction between *D. nigrofasciatus* and *D. intermedius* was not recognised, so that the figures for the former include the latter. As *D. intermedius* appears to be a somewhat rare species, however, this probably does not introduce any very serious error. The migration was a very large one : concentrated in the earliest fields both species reached a peak density of between 6,000 and 7,000 adults to an acre, which, had counts been taken over early and late fields as well, would have meant a total migrant population of about 2,500 to an acre of both species distributed over the whole Station. This migration must have started in early March and extended over about a month. It must be remembered that curves for total migrant population represent a summation of two separate and distinct phenomena. Firstly, successive waves of migrants arriving in the field, and secondly, successive reductions of the population so built up by natural mortality reinforced by secondary migrations out of the field. The so-called peak of a migration is reached when the numbers entering the crop are equal to the numbers dying in or leaving it. The time at which stainers are entering the crop in their greatest numbers lies at the point of inflexion where the population curve is rising most steeply. One may therefore say that if the whole population curve for the migration covers, say, six weeks, only the first three weeks of this are occupied by stainers actually flying into the crop, the latter three representing the successive reduction of the population so created by mortality or secondary migrations ; also, that the point at which stainers are coming into the crop in greatest numbers lies roughly one to one and half weeks before the peak population density is reached.

The F_1 of *D. nigrofasciatus* developing from this migration and remaining in the fields counted was very much smaller than the migration itself and the F_1 of *D. fasciatus*. This might be explained partly by a more pronounced migratory habit on the part of *D. nigrofasciatus* and partly by the fact that the reproductive rate of this species on cotton is lower than that of *D. fasciatus*.

The distinction between the parts of the curve representing the migrant and the F_1 population is very much clearer in 1931 than in successive seasons. This is accounted for by the fact that the minimum following the maximum or peak of migration is reached when the number of adults dying or flying out of the field is equalled by the number of adults produced in the field as an F_1 derived from the early part of the migration. Where counts are taken on early fields with later fields in the vicinity, as was the case in this year, the number of adults produced in the field and staying there is much diminished by secondary migrations to later and more attractive cotton. There is thus a diminution in the effectiveness of the F_1 in offsetting the loss due to mortality amongst migrants, consequently the point of minimum population occurs later and comes lower than would be the case where the whole of the F_1

remains in the field. Where the F_1 is large and permanent, this minimum point is frequently almost obscured and appears only as a point of inflexion in the population curve. This is shown in figs. 5 and 6.

It appears to be generally agreed that the 1931 infestation was the severest ever experienced on the Cotton Station.

1932.—In this season a continuous record of the population of stainers in the crop over the whole Station was taken for the first time. From the previous year's results, it was evident that counts on early or late fields only give a very erroneous conception of the course of the general infestation, owing to the movements of stainers about the Station. It was therefore decided to take counts on every field of cotton.

A single native observer made daily counts of adult stainers on one plant in every row of every field, the plants being those approximately falling on a diagonal across the field. Stainers were not collected, but a pencil stroke for each adult stainer seen irrespective of its species or sex, was made in a note book. When the infestation grew very heavy, it was necessary to employ two observers and reduce the number of plants counted. A sample of the fields ranging from 0.6 to 1.3 per cent. was thus counted. The method is subject to severe criticism for general use, as so much depends upon the integrity of the observer. By changing the fields counted by the two observers daily, it was possible to test the consistency of their two sets of records. Considerable variation between the sets was evident, but they were consistent within themselves—it was, in fact, possible to construct regression curves of the one observer upon the other—so that one may attach a fair degree of significance to the results. The proportions of species and sexes in the population were estimated by collecting and analysing the catch on a diagonal over two 4-acre blocks, one planted 11th November, and the other 16th December, these representing the conditions on early and late fields respectively. The curves in fig. 2 are obtained by applying the proportions so derived to the figures for total adult population obtained in the main count.

As will be seen from fig. 2, *D. nigrofasciatus* and *D. fasciatus* again arrived almost simultaneously, apart from a small early migration of *D. fasciatus* into the plant cotton from neighbouring ratoon fields where this species had overwintered. The peak of the migrant population was about a week later than in 1931, and *D. fasciatus* was always more abundant than *D. nigrofasciatus*, although in both cases the initial migration was very much smaller than in the preceding year.

The F_1 developed was extremely large, but mainly composed of *D. fasciatus*, showing the difference in reproductive rates between the species. *D. intermedius* was scarce throughout the season, in fact, negligible compared with the other two species.

1933.—Following the experience gained in 1931 and 1932, it was evident that in order to obtain a picture of the stainer infestation on cotton in the district as a whole, considerable modifications and expansions of the methods used to obtain population records were required. A further incentive to the evolution of a satisfactory method of wide applicability but simple design was the movement in favour of co-operation in insect pest recording between the various Southern African Stations of the Empire Cotton Growing Corporation.

The objects in taking these records on stainers are, for any given cotton-growing district and for every species of stainer occurring there :—

- i. To determine the time at which stainers migrate into cotton from their wild host-plants.
- ii. To measure the duration and intensity of this migration.
- iii. To estimate the increase due to breeding of migrant stainers in the lands and the time taken for such increase to appear.

Records derived from a single Station may be quite unrepresentative of the district, so that, wherever practicable, records must be taken on a number of farms representing such diversities—whether of situation or of farming practice—as may occur within that district

Records are best taken on sample areas drawn from large uniform areas of cotton, as in this way one eliminates the disturbing effects due to closely adjacent areas of comparable size supporting cotton crops in different stages of attractiveness. Experimental stations are consequently rather unsuitable as recording areas, owing to the diversity of strains of cotton grown and of treatments given to different fields.

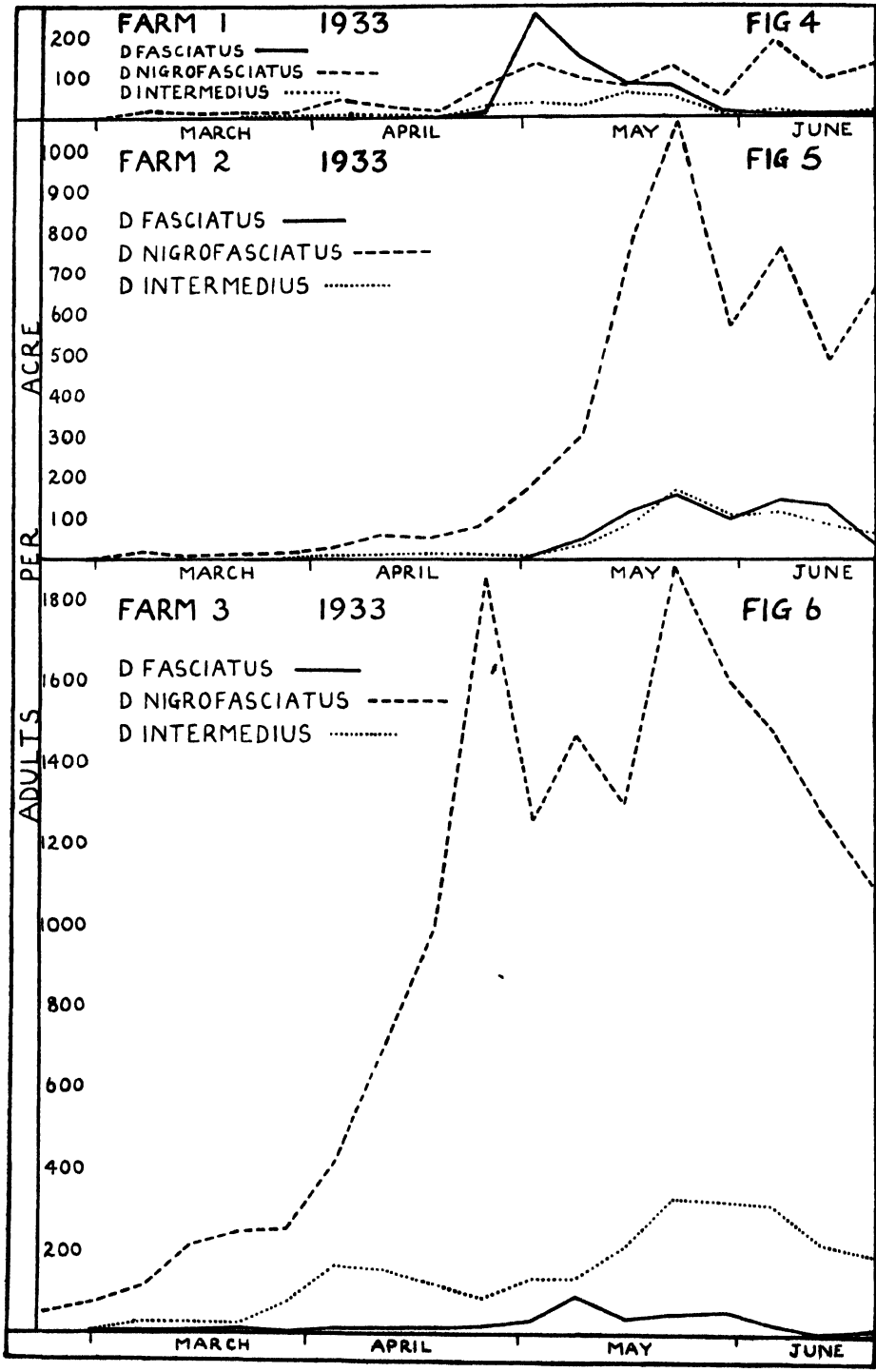
In the past season (1933) counts were taken on four farms in the Barberton area in addition to the Cotton Experiment Station, which was included for the sake of continuity. A uniform method was used in taking these counts and the same method was employed in making counts at three points in Swaziland and at Magut, Natal. The method adopted was as follows :—

- i. All counts were made over a sampling area of ten acres, this being chosen wherever possible within a considerably larger area of cotton.
- ii. Forty units, each $\frac{1}{40}$ of an acre, comprising in all 5 per cent. of the total sampling area, were taken within it.
- iii. Each unit consisted of a certain length of two consecutive rows up which native collectors moved, one on each side of the rows, collecting all the adult stainers on the plants and the ground between each other, *i.e.*, over a strip 6 ft. by 30 yds. or 7 ft. by 26 yds., according to the inter-row spacing in use.
- iv. Collections were made once weekly, starting from the time when the crop was flowering freely and continuing through the season.
- v. Successive weekly counts were taken over the same units, the positions of which were marked with droppers at either end. It was found that the damage done to the plants by the collectors was negligible, and it was assumed that the units were so small that collections would not diminish the total population to any extent and that the units would be re-populated from adjacent rows during the week intervening between successive collections.
- vi. Stainers were collected into tins of paraffin and water, strained off into a smaller tin, collections from all the units being bulked together, and counted. In 1933 the stainer population was so small that whole collections could be counted without difficulty, but in years of heavy infestation a weighed sample would have to be counted to give the numbers of each species and sex.

At all places other than the Cotton Experiment Station and Farm 3, the units were arranged *en échelon* across the field, as in Engledow's Systematic Sampling method. A good collective sample of the whole of the ten acres was thus obtained without any attempt at assigning a significance to the populations recorded.

On the Cotton Experiment Station modifications had to be introduced in order to sample fields in different stages of growth; fields were classified into groups according to their condition at the time when counts started and units systematically arranged over them in numbers proportional to the area of the groups as a whole, so as to obtain a weighted estimate of the total population on the Station.

The results of the counts in 1933 are given in figs. 3–9 inclusive. The notable fact about this season is the scarcity of *D. fasciatus*. The maximum population of this species on the Cotton Station, Barberton, in 1933 was 145 per acre (see fig. 3), whereas in the preceding season it was 14,500 per acre. Figures prior to 1933 are not available for the other farms, but it is known that in 1932 *D. fasciatus* assumed epidemic proportions in many parts of the Barberton district, whereas in 1933 on none of the farms on which counts were made did it exceed a density of 250 per acre.



D. nigrofasciatus, on the other hand, was present in numbers similar to those obtaining in previous years. The following data show the infestations on the Cotton Experiment Station :—

				Peak Populations.		Reproductive Rate
				Migrant	F ₁	
1932	...	...	...	810	3,150	× 3.9
1933	...	...	...	568	2,362	× 4.2

D. intermedius was also present in numbers comparable to, but slightly larger than, those of 1932, reaching a density of 400 per acre.

The above general conditions applied on every farm. There were, however, considerable differences between farms, which are discussed below. These are of considerable interest in connection with the bearing of field conditions on stainer population density.

All recording areas in the Barberton district and also that at Bremersdorp, Swaziland, were situated in country which is intermediate in character between the Middle Veld and the Lower Bushveld. The other recording areas were all in the Lower Bushveld.

Farm 1 (fig. 4). Light sandy soil, exposed situation, 3ft. by 3ft. spacing, poor stand, late. There was very little cover on this farm, and the stainer population was extremely low. The sudden increase of *D. fasciatus* in late April is due to a secondary migration, not to breeding *in situ*.

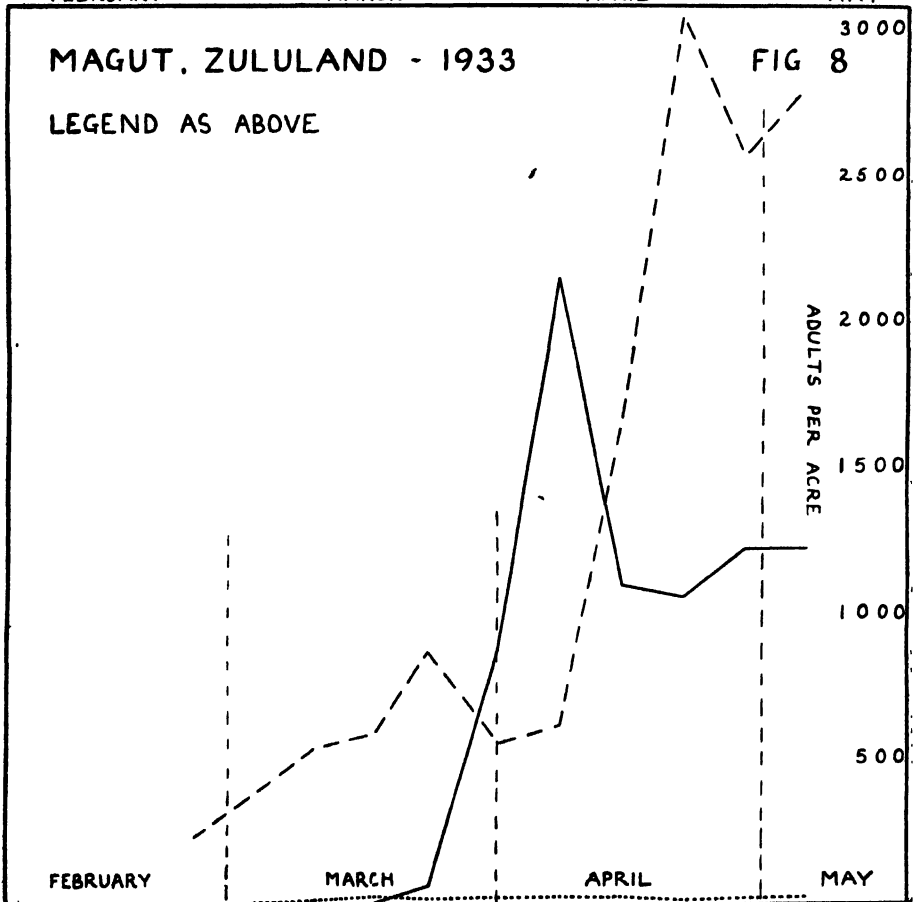
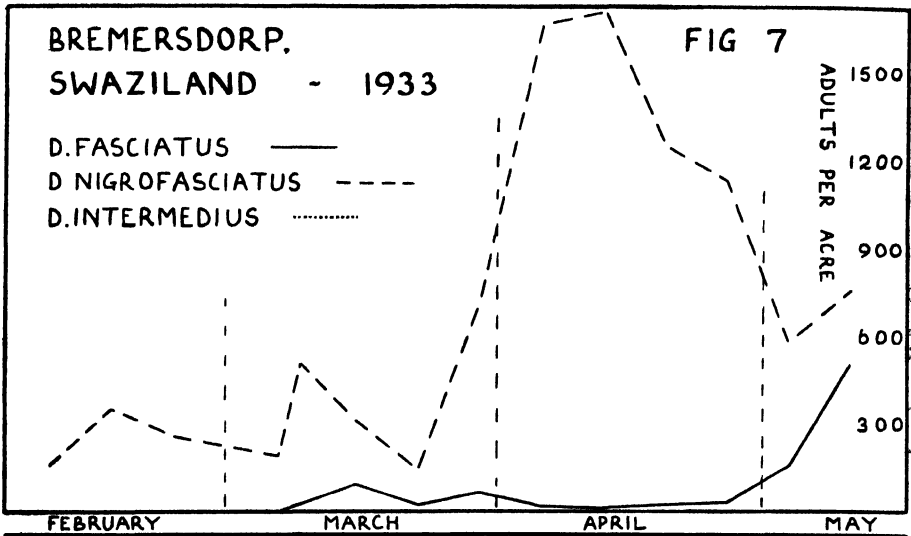
Farm 2 (fig. 5). Light granite soil, exposed situation, 3 ft. by 3 ft. spacing, good stand, rather late. There was more cover here than on Farm 1, but the population was again low. The rapid increase in mid-May of all three species is partly due to breeding in the field, but judging from the small proportion of freshly moulted adults in the catches on these dates, it seems probable that a secondary migration was also involved.

Farm 3 (fig. 6). Sandy loam, sheltered situation, 3 ft. 6 in. by about 1 ft. spacing, dense stand, early. The very close spacing combined with drought in February caused severe wilting and early ripening of the crop. The effect of cover is well marked in the stainer population; the early ripening brought in stainers earlier than they came to the Cotton Station, though in smaller numbers, but the better cover on the farm is probably responsible for the higher reproductive rate here (ninefold increase in F₁) than on the Station (fourfold increase in F₁).

Farm 4. Light granite soil, sheltered situation, 3 ft. by 3 ft. spacing, fair stand, early ratoon cotton. *D. nigrofasciatus* came in early but never reached a density of more than 90 to the acre, whilst the other two species were practically absent. The crop ripened off rapidly on account of drought and was harvested in excellent condition in April, when counts were discontinued.

Bremersdorp, Swaziland (fig. 7). Records were taken on a farm some three miles from Bremersdorp, on cotton planted in poorish, wasted land in October; the plants were never very big, were closely spaced and adjacent to a later field of big plants. Migrants of *D. nigrofasciatus* were coming in on 1st February. The course of infestation was similar to that of Barberton, with *D. nigrofasciatus* predominating, but *D. intermedius* was practically absent.

Ingwavuma, Swaziland (fig. 9). Records were taken on a field of well grown ratoons of which bolls were opening in early February, with a heavy crop set, though somewhat damaged by bollworm. The plants went off badly in mid-March owing to the cessation of rains, and there was practically no crop reaped. This was the only point besides Magut where records were taken for 1933 where



D. fasciatus was ever at all numerous, and it seems almost certain that the infestation here was derived from stainers breeding continuously in the very extensive areas of abandoned cotton on the adjacent lands of Cotton Plantations Ltd. In early February these abandoned lands, though largely reverting to rough pasturage, were carrying patches of fruiting plants on which were colonies of adults and fifth instar nymphs of all three species of stainer, *D. nigrofasciatus* predominating and *D. intermedius* least numerous. The absence of nymphs below the fifth instar suggested that this was the tail end of a generation of which the newly moulted adults were migrating from the fields without laying eggs. At the same time a small migration was in progress to the field in which records were to be taken, the relative abundance of the three species being the same as in the abandoned cotton.

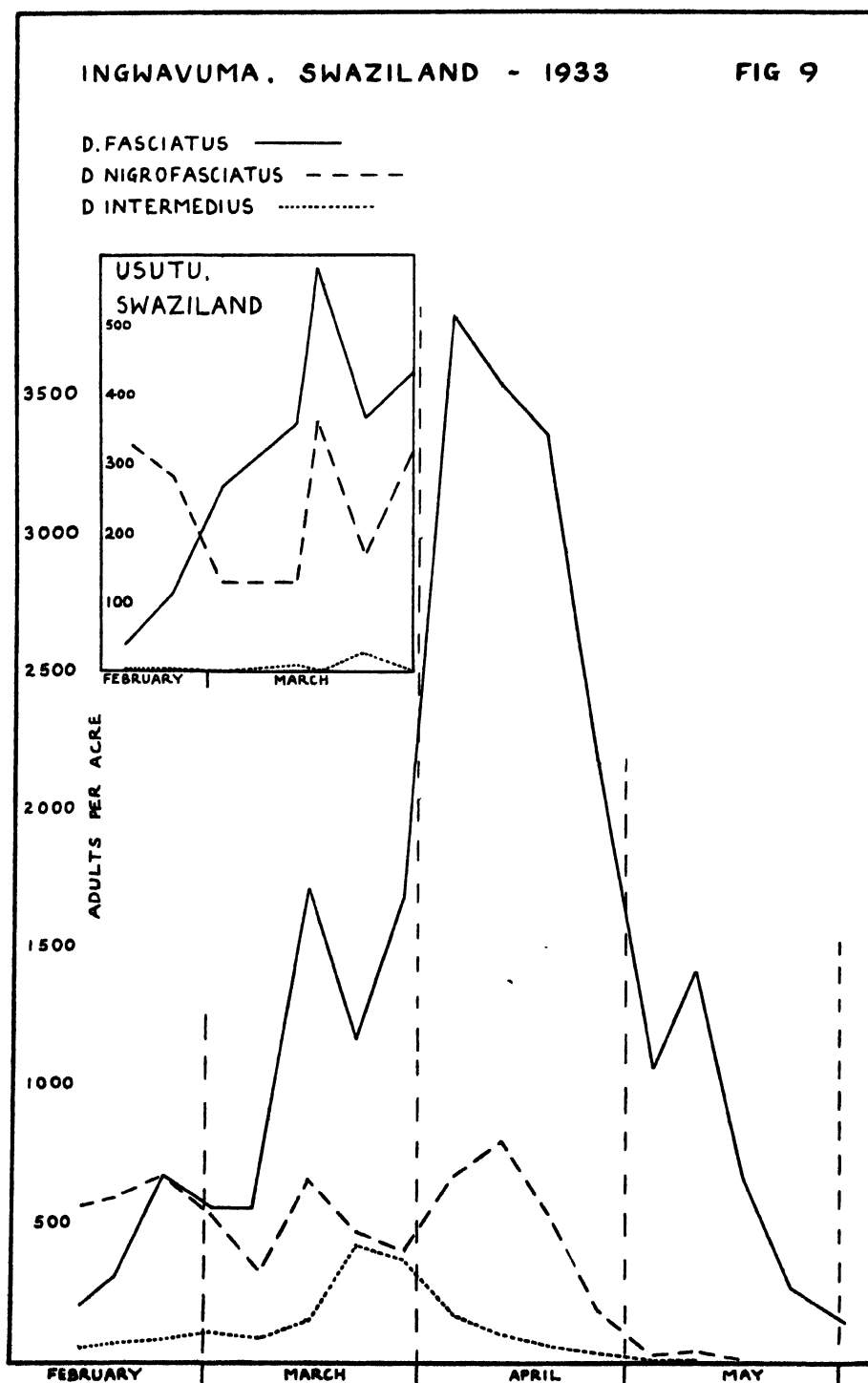
The fairly high initial infestation of *D. fasciatus* gave rise, as at Barberton in 1932, to a very large F_1 (about sixfold) increase. On the other hand, *D. nigrofasciatus*, although the peak of the migrant population was the same as that of *D. fasciatus*, did not give rise to a large F_1 . This again is similar to the conditions on the Cotton Experiment Station at Barberton in 1931 and 1932, *D. nigrofasciatus* having a lower reproductive rate on cotton than *D. fasciatus*, a character which may be more pronounced in the presence of large numbers of the latter species.

Usutu, Swaziland (inset fig. 9). Records were taken on a field of about 50 acres of ratoons, on which a large crop had set by early February, with a few bottom bolls opening and a migration of stainers to the crop just commencing, consisting of *D. nigrofasciatus* with an occasional specimen of *D. intermedius*. The field went off badly owing to beetle damage and drought in March. *D. fasciatus* came in very much later than *D. nigrofasciatus*, but unfortunately counts had to be suspended before the F_1 was reached.

Magut, Natal (fig. 8). Records were taken on ten acres of plant cotton on the Experiment Station. Adjacent areas of ratoon cotton examined on 6th February showed the presence of overwintering *D. fasciatus* and of what appeared to be a fresh migration of *D. nigrofasciatus*, but a complete absence of *D. intermedius*. The ratoon on the Experiment Station was cut out in mid-February, but there was a large area left on the next farm. This probably accounts for the nature of the infestation on the recording area. *D. nigrofasciatus* arrived in mid-February, being probably part of the same migration as was observed entering the ratoon on 6th February. *D. fasciatus* did not arrive until the latter part of March, and from the numbers in which it came, it seems almost certain that this migration was composed of the F_1 from the generation of adults which was observed developing in the adjacent ratoon in early February. The F_1 of *D. nigrofasciatus* developed *in situ* was large, possibly on account of the absence of a maturing F_1 of *D. fasciatus*.

The results of the three years' records of stainer population in the crop may thus be summed up as follows :—

- i. In the absence of adjacent ratoon or standover cotton, stainers begin to appear in plant cotton towards the end of February or the beginning of March, the migration occupying a period of about a month. The peak population of the F_1 is reached about one month after the peak population of the migrant stainers.
- ii. *D. nigrofasciatus* usually appears rather earlier than the other two species.
- iii. *D. intermedius* does not enter the crop in large numbers and once there does not appear to increase very greatly in the subsequent generations. *D. nigrofasciatus* and *D. fasciatus* vary greatly in the relative size of their initial migrations, but *D. nigrofasciatus*, especially in the presence of large numbers of *D. fasciatus*, has a much lower reproductive rate than the latter species.
- iv. Early fields of plant cotton, or fields of ratoons, attract the stainer in first. Where cotton is grown in the neighbourhood of standover cotton or of ratoon



which has not been completely cleaned up at the end of the previous season, the initial infestation is higher, particularly of *D. fasciatus*, than where such breeding grounds are not available.

Statistical Analysis of Population Records.

Previous workers have employed diverse methods of estimating the populations of stainers on different Stations, but most, if not all, of these methods have consisted in collecting stainers on a compact block of cotton without any attempt at sampling a field or estimating the significance of the population figures which they obtain. The method described below, used on Farm 3, was adapted from that of Clapham (J. Agric. Sci. 9, p 228, 1929) and was an attempt to obtain a good estimate of the stainer population on a large field and at the same time to attach some degree of significance to that estimate without being unduly cumbersome in operation.

M = Mean population per sample.

σm = Standard deviation of mean population per sample.

$\frac{100\sigma m}{M}$ = Coefficient of variation.

Date	Pop. per acre	M	σm	$\frac{100\sigma m}{M}$	Nearest significantly different value of M.			
					+		-	
					Date	Difference	Date	Difference
22/2	62	3.1	2.57	83.0	15/2	7.4	—	—
1/3	74	3.7	1.19	32.2	15/3	6.8	—	—*
9/3	116	5.8	1.75	30.1	22/3	6.5	—	—*
15/3	210	10.5	1.75	16.7	5/4	10.5	1/3	6.8
22/3	246	12.3	2.62	21.3	5/4	8.8	9/3	6.5
29/3	256	12.8	2.72	21.2	5/4	8.3	9/3	7.0
5/4	422	21.1	3.44	16.3	19/4	28.5	29/3	8.3
12/4	688	34.4	7.29	21.2	19/4	15.2	29/3	21.6
19/4	992	49.6	7.60	15.3	10/5	23.7	12/4	15.2
26/4	1,854	92.7	15.38	16.6	—	—	20/6	37.4
3/5	1,256	62.8	8.85	14.1	23/5	31.2	12/4	28.4
10/5	1,466	73.3	8.71	11.9	—	—	19/4	23.7
16/5	1,294	64.7	12.61	19.5	23/5	29.3	12/4	30.3
23/5	1,880	94.0	11.76	12.5	—	—	16/5	29.3
31/5	1,598	79.9	7.32	9.2	—	—	20/6	24.6
6/6	1,474	73.7	5.97	8.1	—	—	20/6	18.4
13/6	1,268	63.4	7.21	11.4	23/5	30.6	12/4	29.0
20/6	1,106	55.3	3.10	5.6	6/6	18.4	12/4	20.9

*Differ significantly from zero.

The field used was between 30 and 40 acres in size, from well within which a 10 acre block was selected. On this block 40 units of $\frac{1}{10}$ acre each were arranged in 10 samples of 4 units each. The field was divided into four longitudinally and the position in the first quarter of the field of the first unit of each of the 10 samples was found by randomising for row and position in the row. The remaining three units in each of the samples fell one in each of the remaining quarters of the field, the row on which it was placed being the same as the row on which the first unit fell in the first quarter, the position in the row being determined by moving an arbitrary distance up the row. In this way 10 independent samples of the field were obtained, each consisting of 4 units regularly arranged so as to cover the field. The stainers collected on all of the 4 units of a sample were bulked together. Four natives accompanied by a European assistant were able to make the collection in half a day.

The table (p. 393) shows the analysis of the population of adults of *D. nigrofasciatus* on successive weeks.

In testing the significance of the difference in population on two separate fields each supplying data similar to that given above, the usual method of testing the significance of the difference of means of two independent samples must be used. This method may also be employed in testing the significance of the difference in population on different occasions in the same field. Where, however, as in this method of stainer recording, the same plants are used throughout the season, it is legitimate, and sometimes more precise, to take for each sample the difference in stainer population between the two occasions and test whether the mean difference is significantly greater than zero. The application of the two methods to a pair of occasions from the above data is given below.

Test of significance of difference in populations on 16th and 23rd May

Sample	Number of adults of <i>D. nigrofasciatus</i> per sample		
	23rd May	16th May	Difference
1	70	42	+ 28
2	100	40	+ 60
3	85	74	+ 11
4	90	49	+ 41
5	190	161	+ 29
6	59	46	+ 13
7	91	68	+ 23
8	59	18	+ 41
9	94	54	+ 40
10	102	95	+ 7
Total	940	647	293
Mean	$M_1 = 94.0$	$M_2 = 64.7$	$M_1 - M_2 = 29.3$
Standard Deviation of Mean	$\sigma_1 = 11.76$	$\sigma_2 = 12.61$	$\sigma_{1-2} = 5.24$

Method 1. Assuming the two sets of samples to be independent.

$$M_1 - M_2 = 29.3$$

$$t = \frac{M_1 - M_2}{\sqrt{\sigma_1^2 + \sigma_2^2}} = 1.70 \quad \text{Degrees of freedom, } n = 18$$

$$P > 0.1 < 0.2$$

Method 2. Assuming the two sets of samples to be correlated.

$$M_1 - M_2 = 29.3$$

$$t = \frac{M_1 - M_2}{\sigma_{1-2}} = 5.59 \quad \text{Degrees of freedom, } n = 9$$

$$P < 0.01$$

It will be observed that whereas by Method 1 the value of P far exceeds the conventional 5 per cent. level of significance, by Method 2 the difference between populations on the two dates is shown to be very highly significant.

From the table given above it will be seen that while values of M on consecutive dates do not usually differ significantly and while, in fact, the percentage differences in population required to attain significance are definitely high, it is nevertheless possible to demonstrate significant differences between values of M at salient points on the population curve and thus to establish the approximate shape of the curve.

The field used was severely affected by drought comparatively early in the season and developed an irregular series of patches of very varied cover, the effect of which was to concentrate the stainer population in the areas of good growth throughout the season. Certain units consistently gave a high yield of stainers, others consistently yielded few or none; fig. 10 (p. 396) shows this graphically for *D. nigrofasciatus* on three dates—15th March, approximately the peak of density of the migrant population, 19th April, when the maximum production of the F_1 was in progress, and 23rd May, the date of maximum population for the season, composed of a mixed F_2 and F_3 . At no time during the major part of the season was there such diffusion outward from these foci of infestation as might lead to a uniform "saturation" of the field by the insect. This probably accounts for the fact that the coefficient of variation, $\frac{100\sigma m}{M}$,

is so remarkably constant over such a wide range of values of M . In view of this exceptional irregularity developed over the field, the method may be regarded as having been tolerably successful and forms a useful basis for lay-outs to be used in future at all points where stainer populations are being recorded.

Ratoon and Standover Cotton in relation to Stainer Infestation.

The importance of ratoon and standover cotton in connection with stainer infestation cannot be too strongly emphasised. Abandoned fields, or ratoons that have not received a proper clean-up, are always liable, if there is any shade or crop available, to breed stainers continuously through the winter. These proceed to migrate to the new crop as soon as it is set. *D. fasciatus* appears particularly to favour this method of overwintering, and as this species, on account of its high reproductive rate, is the most dangerous of the three, it further emphasises the undesirability of cotton in this state. This was clearly shown in the present year, 1933, where *D. fasciatus* as a whole was noticeably absent from all places, except those where it was believed to have overwintered in standover cotton. Even cotton which has been carefully ratooned and cleaned up is a potential danger to any plant cotton, as by reason of its earlier get-away it is in a condition to attract in any wandering stainers considerably before plant cotton does so.

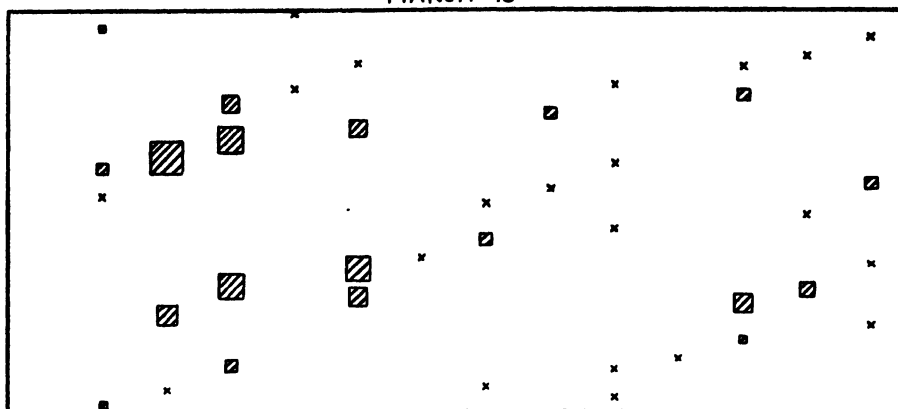
FARM 3 - 1933

FIG 10

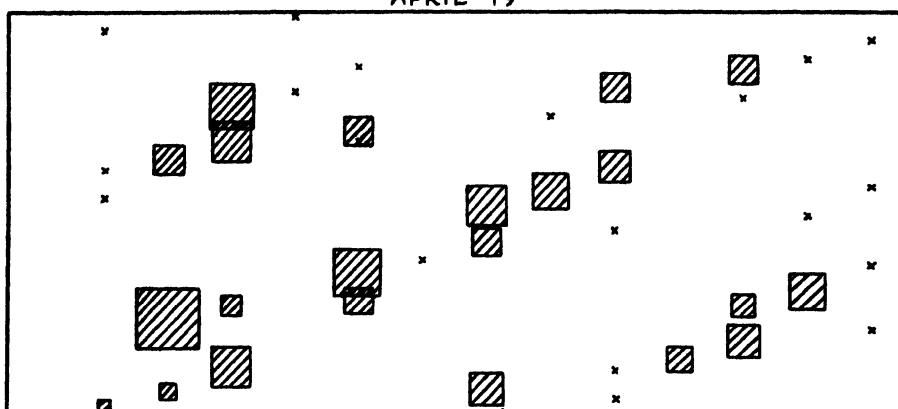
POSITION OF SAMPLING UNITS AND DISTRIBUTION OF *D. NIGROFASCIATUS*

AREAS OF SHADED SQUARES PROPORTIONAL TO NUMBER OF ADULTS COLLECTED AT THOSE POINTS: CROSSES INDICATE CENTRES OF SAMPLING UNITS ON WHICH NO ADULTS OCCURRED

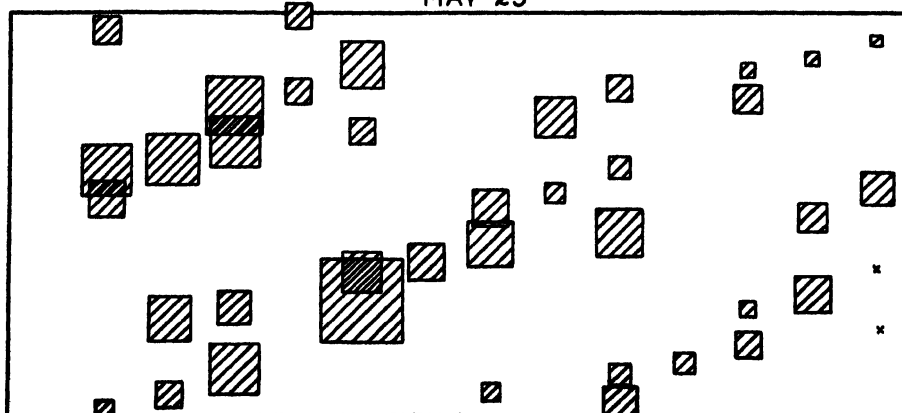
MARCH 15



APRIL 19



MAY 23



On the Cotton Experiment Station, season 1931-32, partly as a result of overwintering of *D. fasciatus*, but more especially on account of early migration into these fields, the population on the ratoon plots kept for bollworm experimental work rose as follows :—

10th Dec. 1931,	140	per acre of all species of <i>Dysdercus</i> .
17th Dec. 1931,	140	“ “ “ “
20th Jan. 1932,	700	“ “ “ “
10th Feb. 1932,	3,000	“ “ “ “

The area was fortunately small, but even so the population built up there was sufficient to start a small early migration into the plant cotton considerably before the main migration occurred (see fig. 2, 1932, mid-March).

On the Premier Cotton Estates in the same year there was a very large acreage of ratoons into which stainers (*D. fasciatus* and *D. intermedius*) migrated direct from their wild food-plants in early February. An enormous F_1 had been built up by mid-March, of which the later plant cotton received the full force. The ratoon crop gave quite a good yield of clean cotton, but the plant cotton was very badly stained.

On the Cotton Experiment Station in 1932 there was a sudden and heavy migration, largely composed of *D. nigrofasciatus*, into the ratoon crop in late November and early December, reaching a peak population density of 1,000 per acre. This was checked by hand collecting and plant stripping, but it is easy to imagine what the effect on the plant cotton might have been the following March had this infestation been allowed to persist. A similar but smaller migration into opening ratoon cotton appeared on an adjacent farm in mid-January, a long time before any stainers appeared in the plant cotton. The migration to the ratoon cotton in which counts were made at Farm 4, Barberton, shows the same early character, as do also the migrations to ratoons at Usutu and Ingwavuma, Swaziland.




It seems to be the case that from January onwards stainers, particularly *D. nigrofasciatus*, are moving out from their wild food-plants and are liable to be attracted into any early opening crop. From the point of view of that crop itself, this may not be a very serious matter, the real damage being done to the later, main crop of plant cotton. Consequently, whilst the presence of abandoned cotton constitutes a major source of trouble on account of the facilities afforded, especially to the most dangerous species, of continuous breeding through the winter, the practice of growing even properly ratooned cotton in close proximity to plant cotton is scarcely less open to criticism. Separately, both ratoon and plant cotton have their advantages. Together, they are frequently disastrous.

Wild Food-plants.

The first observations on possible wild food-plants of the stainer in the Barberton district were made by Mr. F. S. Parsons of the Empire Cotton Growing Corporation, Barberton, in 1930, on an isolated specimen of *Sterculia rogersii*. Since that time, the identity and distribution of the probable food-plants of the stainer have been established with a considerable degree of certainty throughout the whole of the Transvaal Lowveld, whilst rapid tours have given some indication of their occurrence in Southern Rhodesia, Portuguese East Africa, Swaziland and Zululand. In addition, detailed observations have been made on such of these plants as occur in the Barberton district, to determine their fruiting habits and the abundance of stainers on them through the year.

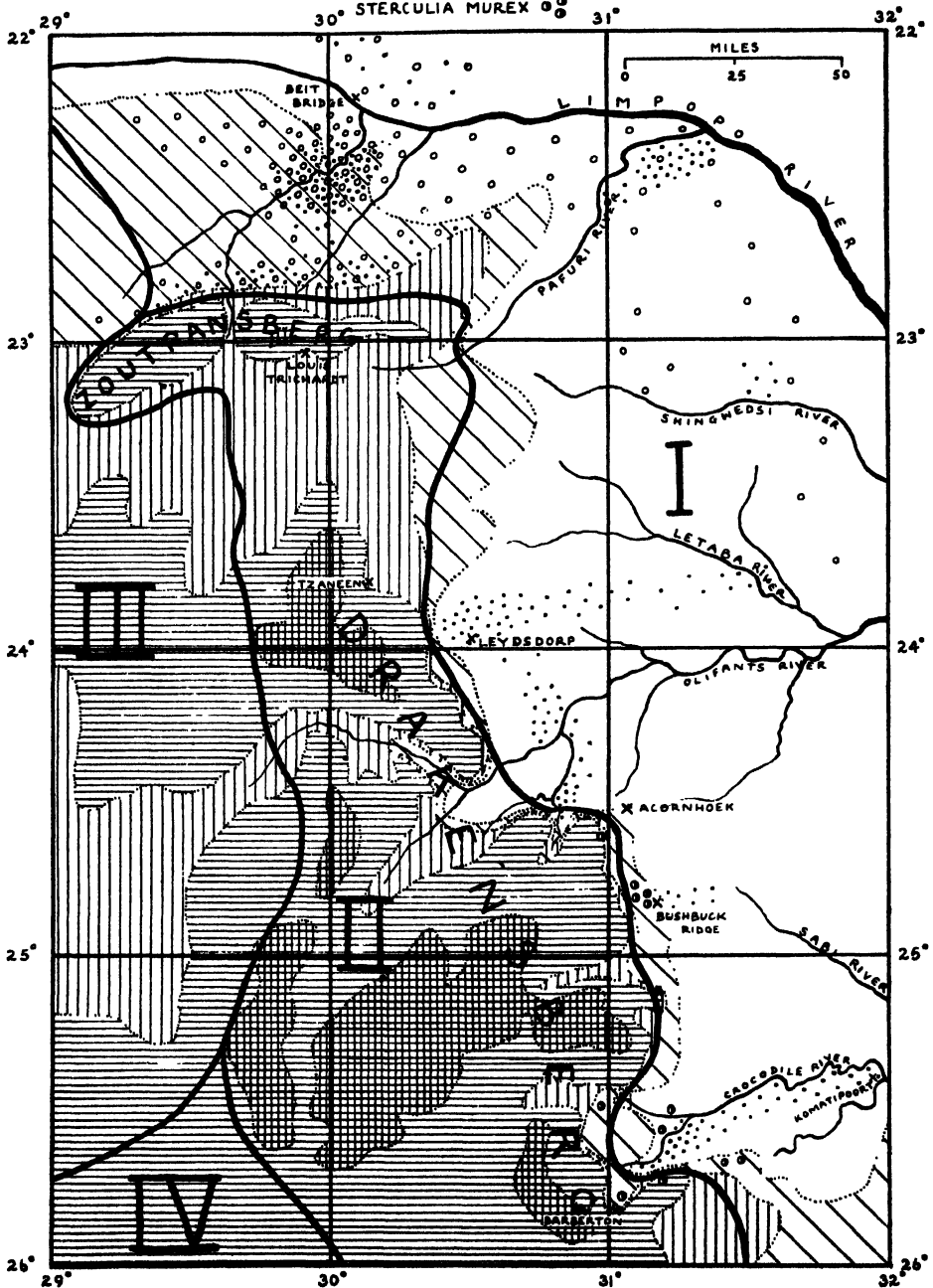
The following notes embody the results of periodical collecting trips through the De Kaap Valley and the Lowveld along the Barberton-Komatipoort Road in the years 1930-33, an intensive collecting survey of the De Kaap Valley made at the Corporation's instance by Mr. J. Thorncroft, Jr., of Barberton, in the summer of 1932.

SKETCH MAP OF THE EASTERN TRANSVAAL

ALTITUDES: BELOW 2000 FT.  2-3000 FT.  3-4000 FT. 

4-6000 FT.  ABOVE 6000 FT. 

STAINER HOSTS: ADANSONIA DIGITATA  STERCVLIA MUREX  STERCVLIA ROGERSII 



a brief visit to the Zoutpansberg and the country northwards to Messina made by Mr. Parsons and the writer in the summer of 1932, and an extensive tour of the whole of the North Eastern Transvaal by the writer in the winter of 1933. The area covered thus includes the whole of the Province lying between latitudes 22° and 26° South and longitudes 29° and 32° East.

For the purposes of the present discussion this area may be divided into four botanical provinces :—

- I. Lower Bushveld.
- II. Eastern Mountains.
- III. Upper Bushveld.
- IV. Highveld.

These provinces are roughly outlined on the accompanying map. They correspond roughly, but not exactly, with the divisions given by Burt Davy (Flowering Plants and Ferns of the Transvaal, Vol. I, 1926).

The Highveld proper consists of a practically pure stand of rolling grass land, lying above 5,000 ft.

The Upper Bushveld includes the undulating areas of low rainfall, topographically similar to the Highveld but at lower altitudes, covered with rather small thorn bush, lying between Pretoria and the Zoutpansberg and West of longitude 30° East.

The Eastern Mountains, which include the Drakensberg and Zoutpansberg systems, comprise chiefly mountain grassland with patches of evergreen forest in the mist belt of the Eastern slopes of the Drakensberg and the upper regions of the Zoutpansberg, but also include a narrow strip of foothills and spurs to the east of the mountains, between 2,500 and 3,500 ft., lying directly west of the Lower Bushveld and sometimes described as Middle Veld. This region receives its character from the fact that the mountain escarpment precipitates a fairly high rainfall over this area (up to 40 ins. per annum), ranges of hills of equal altitude lying farther to the east being much drier : it is covered with an orchard type of vegetation of which the dominant species are the Waterhoutboom, the Grysappelboom (*Parinarium mobola*, Oliv.), the Beukenhout (*Faurea* spp.) and, on the lower slopes, the Transvaal Teak (*Pterocarpus angolensis*, DC.).

The Lower Bushveld consists largely of gently undulating plains of more or less open woodland, the dominant species depending upon the latitude. North of the Olifants River (Lat. 24° South) this is the Mopani (*Copaifera mopane*, Kirk.), whilst south of it the Acacias predominate. Within the area, however, three distinct regions occur in addition to the open woodland type of vegetation :—

- i. Much dissected country towards rivers, or low ranges of hills determining the course of the latter, subject to considerable wash, exposing surface rock. The vegetation is similar to the surrounding bushveld but added character is given to it by the variations in the exposure and drainage.
- ii. Extensive vleis, which in the northern part of the region consist largely of swamp grass with clumps of palms, and in the southern part appear as savannahs of grass and flat-topped Acacias.
- iii. Numerous and in some cases extensive outcrops of metamorphic rock forming long ridges, mainly running east and west, which may break up into strings of kopjes or isolated bosses. The extremely steep northern slopes of these outcrops, on account of the resultant exposure and broken rock masses, support a scanty xerophytic or strongly deciduous vegetation, frequently associated with Euphorbias, differing widely from that of the surrounding bushveld. Regions of the same vegetative type also occur on the lower northern slopes of the Zoutpansberg and the Swaziland Hills, where a steep exposure is combined with a low rainfall.

The wild food-plants of stainers are confined to the families Malvaceae, Sterculiaceae and Bombaceae. These three families attain their greatest importance in the Lower Bushveld (I) and the lower section of the Eastern Mountains (II) Provinces. In the Upper Bushveld (III) and Highveld (IV) Provinces they are poorly represented by herbaceous or shrubby species only. A great many of the species within these families are comparatively rare and thus are of little importance in the present connection. Others are abundant, but do not appear to be favoured as a source of food by stainers: these include the very extensive genera *Dombeya* and *Waltheria* in the Sterculiaceae. Those members of the three families which are definitely known to be efficient hosts of the stainer may conveniently be considered in two groups: firstly, herbaceous and shrubby species; secondly, arboreal species.

Group I. Herbaceous and Shrubby Species.

Gossypium herbaceum var. *africanum*, Watt.

Lower Bushveld. Favours exceptionally dry, sandy localities, usually associated with dense, low thornbush.

Hibiscus aponeurus, Sprague & Hutch.

Lower Bushveld. Moist situations.

Hibiscus calyphyllus, Cav.

Eastern Mountains Province. Shady, moist situations.

Hibiscus dongolensis, Del., *H. subphysaloides*, Hochr., and *H. vitifolius*, L.

Foothills of Eastern Mountains and Lower Bushveld. Exposed positions in open woodland, but rarely on steep slopes.

Sida dregei, Burt Davy, and *S. rhombifolia*, L.

Widespread and common in all parts, especially at roadsides, near kraals and on abandoned land.

Abutilon austro-africanum, Hochr., and a number of related but unidentified species of *Abutilon*.

Lower bushveld. Xerophytic types suited to exposed positions in sandy localities, common weeds of abandoned lands.

All these species are gregarious and commonly occur in small clumps or colonies. Their flowering and fruiting habits are closely dependent on the rains and are consequently somewhat irregular. Taking the region as a whole, there is probably a continuous supply of fruit in all stages of development on most of these species from about October to May. Winter rains may produce a small out-of-season crop, though in the dry winter months the majority of the colonies die back completely, save for those in sheltered, moist situations, on river banks, near irrigation channels, or in the shaded beds of hill streams, where flowering may be continuous throughout the year.

D. nigrofasciatus is the only species that has been taken at all frequently on these plants; it may commonly be found wherever there is a patch of them bearing freshly opened capsules. *D. fasciatus* and *D. intermedius* have been taken on *Gossypium* and *Hibiscus dongolensis* only. Owing to the high degree of variation in the micro-climate associated with these colonies, widely scattered as they are over the broken country of the Barberton district, it is difficult to assess their importance. Records to date are scanty, because in the season 1931-32 information was only beginning to be collected as to the nature of the food-plant flora of the district, whilst in 1932-33 the stainer population as a whole was exceedingly small and the insects were, in fact, difficult to find. Further work of an intensive character is required before the rôle played by this group of plants can be appreciated.

Group II. Arboreal Species.

Three important arboreal hosts of stainers occur in the Transvaal :—

Adansonia digitata, L., the Baobab.

The Baobab is confined to the Lower Bushveld, below 2,000 ft. and it occurs in its greatest numbers and size in the basin of the Limpopo River. There are two main belts running eastward from Long. 29°E., roughly parallel to and north of the Zoutpansberg, the one on the lower foothills of the berg itself, the other along the ridges of hills following the Sand River. Specimens also occur on the flats between the two belts, frequently of very large size, but less numerous than in the hillier regions. The two belts converge and meet at the junctions of the Pafuri and Limpopo Rivers and turn southwards, thinning out as they go. With the exception of a few scattered trees which occur farther south, the distribution peters out at the Olifants River. (See sketch-map.)

The Baobab flowers during the summer, and the fruits ripen off towards the end of the winter following. They are normally shed in August and September, when they constitute the main food supply of baboons, which crack open the husks and feed on the pulp, the seed passing through the digestive tract unchanged. These animals appear to be the main agency in distributing the seed and incidentally in rendering it available for insects.

In spite of the fact that the Baobab is commonly reported as being the main food-plant of *D. fasciatus* in Africa, no stainers have been found in either of the very careful and thorough searches which have been made, in March 1932 and September 1933. It may be that a succession of excessively dry seasons has so far reduced the stainer population in this area, especially in the absence of any cotton in the locality, that none was found or possibly that the trees are only infested between the beginning of the rains and mid-summer.*

Sterculia rogersii, N. E. Br.

This tree is confined to the Lower Bushveld and within that area to sections (i) and (iii). Outside of the Transvaal it has been found in Southern Rhodesia, just north of the Limpopo River, in the Low Veld of Portuguese East Africa, and on the coastal side of the Lebombo Hills on the Swaziland-Zululand border. Probably it extends continuously from Natal to Southern Rhodesia. (See sketch-map.)

With its enlarged, water-storing trunk, spreading roots, inconspicuous foliage and strongly deciduous habit, *S. rogersii* is well adapted to life on the stony, well drained, steeply exposed, northern slopes of hills, kopjes and outcrops, forming frequently large and extensive colonies where such habitats occur. Plate XII shows a typical specimen, one of a large colony occurring on a northward sloping hillside near Barberton. The general type of habitat is well illustrated.

Flowering August–September, the main crop of fruit splits open on the tree from late October to the end of December, though mid-winter or discontinuous rains may induce a number of partial crops. The foliage does not appear until the crop is set, in late October. By February the seed has shed from the dehiscent capsules, which persist on the tree until the following season, and usually rapidly disappears from the ground below the tree, apparently being eaten or collected and cached by small rodents.

Stainers begin to flight into the trees when the fruits dehisce and may be found feeding on the seeds within the split fruits or even through the wall of undehiscent capsules. These migrants are very active and shy, readily taking to flight when approached. Copulation now takes place, and eggs are laid in the soil or debris below

* Since writing the above, the author has received (February and April, 1934) collections of *D. fasciatus* from the Northern Transvaal found feeding inside baobab fruits split open by natives and upon baobab seeds embedded in the droppings of baboons.

the trees. Second instars are commonly found in clusters below or on the surface of the ground, or resting on such small herbs or grasses as occur below the tree, but the nymphs soon find their way up the tree to the split fruits, within which they shelter, feeding on the seeds. Plate XIII shows fifth instar nymphs of *D. intermedius* feeding in split capsules; in fig. 2 one can also distinguish the exuvium of a nymph which moulted from the fifth instar to the adult stage just before the photograph was taken. The position on the underside of the leaf is very characteristic. The number of nymphs which may congregate within the split capsules is enormous; from two bunches of fruit of the same size as that shown in the plate over 400 nymphs of *D. intermedius* were obtained. Such a collection is by no means unusual.

The following records extend over the four years in which observations have been made on *S. rogersii* in the Barberton district:—

- 1930—Mid-November. Stainers (? sp.) fighting into the trees, fruit opening, foliage unfolded.
- 1931—Early March. Migrant stainers appearing in cotton.
 Mid-November. Migration of adults of *D. nigrofasciatus* and *D. intermedius* to the trees, the former preponderating, trees in full fruit, capsules splitting, full foliage.
 Late November. Migration of adults of *D. fasciatus* to trees.
 December. Breeding up of nymphs of all species.
- 1932—January F_1 adults of all species, *D. nigrofasciatus* and *D. fasciatus* in about equal numbers, *D. intermedius* scarce.
 February. Adults decreasing in numbers, small numbers of F_2 nymphs of all species.
- 1932—March. Migrant stainers appearing in cotton.
 Late October. Migration of *D. intermedius* adults to early fruiting trees.
 November. Migration of *D. intermedius* adults to successively fruiting colonies of trees and F_1 nymphs of *D. intermedius* on earliest infested trees.
 December. Half-grown nymphs of *D. intermedius*.
- 1933—January. Small numbers late instar nymphs of *D. intermedius*.
 February. No stainers left on the trees.
 Early March. Migration of *D. intermedius* and *D. nigrofasciatus* adults to cotton.
 November. Migration of *D. intermedius* and *D. nigrofasciatus* adults to trees bearing early crops of split fruit, the former species arriving first.
 December. Nymphs of *D. intermedius* and *D. nigrofasciatus* breeding up on very large main crop, now splitting open, F_1 adults of *D. intermedius* in small numbers on earliest infested trees.

The difference between the three seasons 1931–32, 32–33 and 33–34 is very marked. In 1931 the trees set a fairly large crop and midsummer rains were good. The subsequent infestation in plant cotton, in respect of relative proportions of the three species, was of the same nature as that on the *Sterculia* trees. In 1932 the combined effects of low rainfall right through the early part of the summer, together with the depredations of a Cossid moth larva which feeds on the green fruit, reduced the crop, as well as causing premature opening. *D. nigrofasciatus* and *D. fasciatus* never appeared in the colonies under observation, though *D. intermedius* was more plentiful than in the

previous season. Again the nature of the infestation was reflected in the subsequent infestation on cotton, where the migrant population of *D. intermedius* was larger than in the previous year, that of *D. nigrofasciatus* smaller and that of *D. fasciatus* practically negligible. The season at present in progress (December 1933) has been marked by an early crop of fruit to which *D. intermedius* has come in larger numbers than ever before, followed by *D. nigrofasciatus* a little later. A very large main crop has been set in response to excellent summer rains, and on this both species are breeding. There is every prospect of a large population of these two species being bred up on the trees, but up to date *D. fasciatus* has fortunately not appeared.

It is dangerous to generalise from only a few seasons' experience, but it seems very likely that *Sterculia rogersii* forms the immediate source of the stainer infestation in cotton in the district.

Sterculia murex, Hemsl.

The distribution of this species of *Sterculia* is much more limited than that of the preceding one, being confined to the narrow belt of so-called Middle Veld which lies within the Eastern Mountains Province. It is recorded from Swaziland and occurs in small numbers in the Barberton district, but it has been found in its largest numbers on the Bushbuck Ridge. (See sketch-map.)

It occurs in small groups together of quite large trees, up to 30ft. high, flowers in August–September, at the same time as *S. rogersii*, but the fruits, which are much larger and woodier than those of the latter species, do not split open until after mid-summer. The leaves, which persist from spring to spring, are large and digitate, affording continuous shade on the trees and forming a thick carpet of trash below them. All the trees observed have been abundant fruiters and the late opening and good shelter below the trees, coupled with the fact that they occur within a belt of rather high rainfall, where in addition heavy dews are common, suggest that they may be of considerable importance as overwintering grounds for stainers.

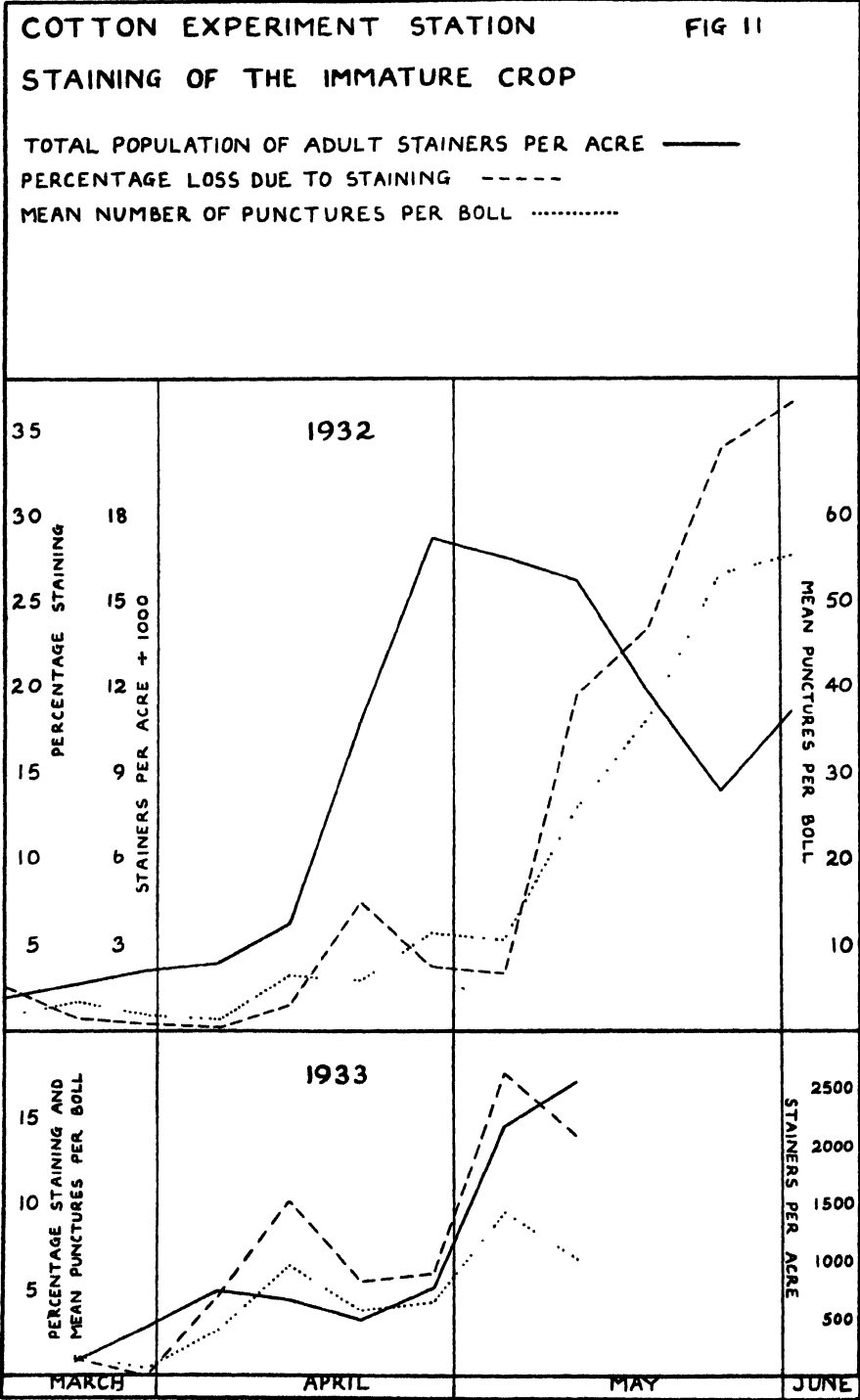
D. nigrofasciatus has been found breeding below the trees in September and in February, and farmers on whose lands trees occur report that at the conclusion of the cotton crop migration of stainers takes place to the trees.

It is uncertain as yet, however, whether the species is sufficiently numerous or widely distributed to be of more than local importance in affording a winter breeding ground for stainers.

In addition to the foregoing food-plants, there is a possibility that *Thespesia* and *Cienfugosia* (Malvaceae) may be of importance in South Africa. The latter genus occurs in large quantities in the Portuguese East African Low Veld and (another species) in the Limpopo basin, but it is not known whether stainers commonly occur on it. Its flowering and fruiting habits are similar to those of the other herbaceous and shrubby food-plants.

Thespesia rogersii occurs in Southern Rhodesia just north of the Limpopo River and according to native reports is found south of the river in the Pafuri district, but it has not actually been observed personally. *Thespesia populnea* var. *acutiloba* (?) has been found in large quantities in Central Zululand, between the Black and White Umfolosi Rivers, occurring as a large bush up to 12 ft. high in sandy hollows, dry river-beds and spruities at altitudes from 1,500–2,000 ft. At the time it was seen (February) it was flowering and bearing only very young fruit, so that it is not known whether stainers occur on it later in the season.

To sum up with certainty at this stage the relations of the three species of stainers to their wild hosts is difficult. *D. nigrofasciatus* appears to be the most catholic in its tastes, and the normal infestation in cotton is probably derived from the overwintering of an exiguous population on herbaceous hosts occurring in sheltered situations, reinforced by mass breeding on *Sterculia rogersii* in the early summer. The



precise limits of its distribution are a little doubtful, but nearer the equator its place appears to be taken to a great extent by *D. supersticiosus*, with which species it may have been confused in the past. It certainly appears better suited to conditions in South Africa, where the larger food-plants are much less numerous than in the tropics and where all the year round food is only supplied by herbaceous hosts.

D. intermedius is a rarer species throughout Africa than the other two, but seems to attain its maximum proportions in South Central and East Africa. It appears to be strongly associated with the genus *Sterculia*, on which it is found in Portuguese East Africa, Nyasaland and the Rhodesias.

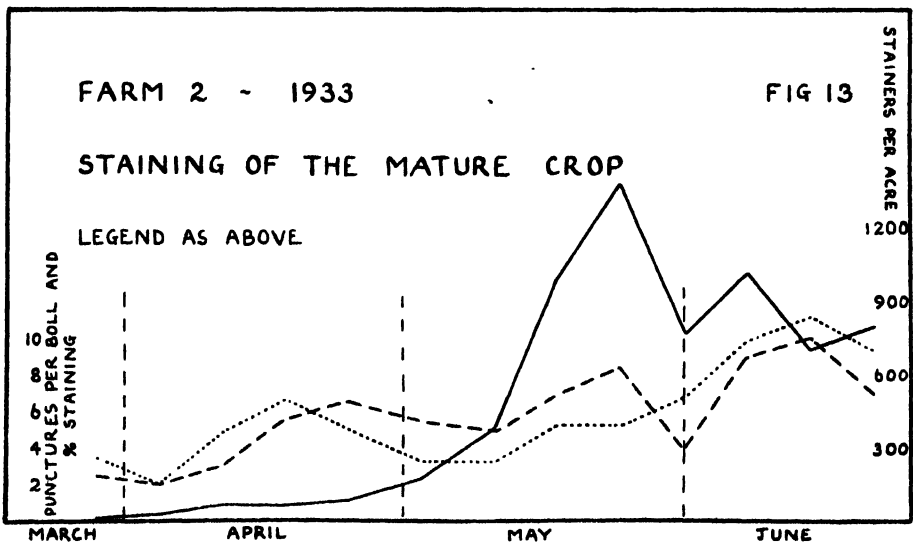
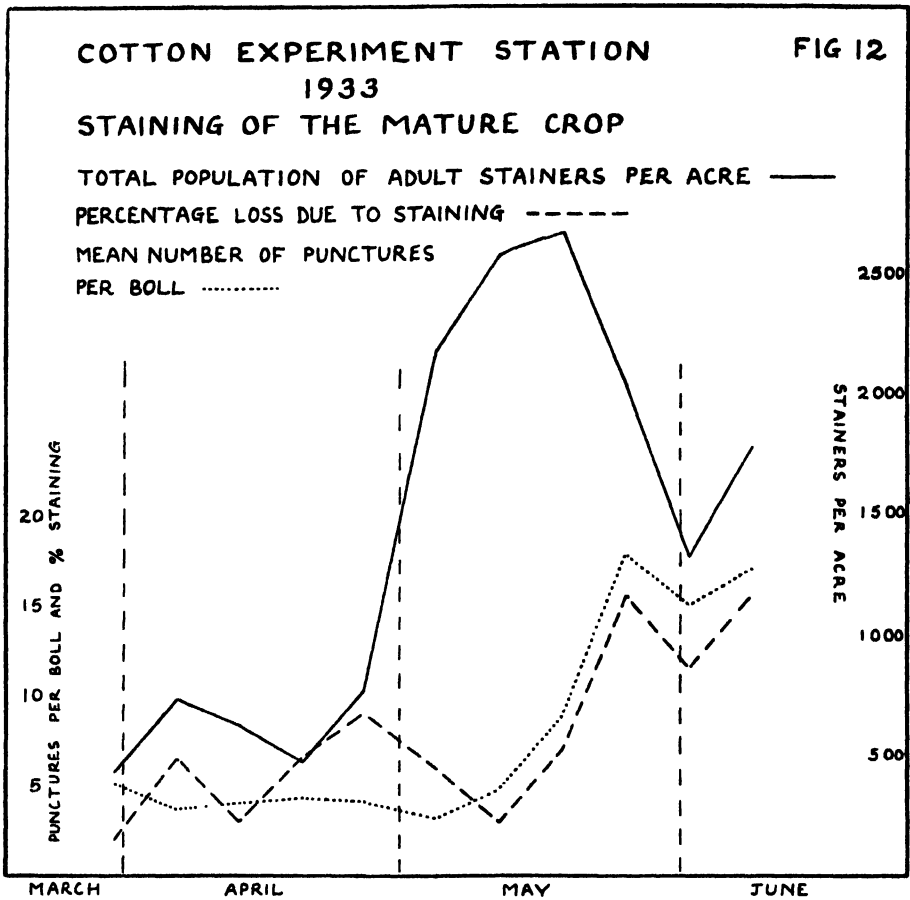
D. fasciatus is the most widely spread of all the African species of the genus ; it does not favour herbaceous plants and appears in this district to depend on standover cotton or a large and late crop of *Sterculia rogersii* as a take-off for plant cotton. Its overwintering habits in South Africa are problematical, but its common association with the baobab, particularly as an overwintering ground, in other parts of Africa suggests that its relation with the baobab belt in the Northern Transvaal requires to be fully investigated.

Damage to the Crop.

It is commonly stated that the amount of staining in the crop is not invariably proportional to the stainer infestation. This is no doubt partly due to the inaccuracy of visual impressions ; it is difficult to assess at all accurately the population in a field, so that to superimpose upon a visual impression of population density a similar estimate of the amount of staining cannot lead to a very significant result. An attempt to clarify the relation between stainers and staining has been made in the past two seasons by making boll collections at points adjacent to those in the fields where population records were being taken. These bolls have then been examined, the number of punctures counted and the bolls graded according to arbitrary standards of staining. The figures so obtained have been reduced to total percentage loss due to staining by estimating, for each of the arbitrary grades of staining, the percentage of stained cotton in a boll of the given grade.

In 1932 the method of boll collection was to strip all the green bolls of a certain size (2.8 cm. diameter upwards) from 20 plants weekly on a 2½ acre field. In 1933 two methods were used : green bolls of a definite size, chosen as that attained by a boll three weeks old under normal conditions, and also bolls which had just split were collected (approximately 80 a week of each type from a 10-acre field). The disadvantages of the 1932 method are that it involves the destruction of stand and that the range in boll size and age renders it difficult to reduce one's results to a simple quantitative measure ; the disadvantages of the use of green bolls in the 1933 method are that the size-age relationship varies as the season advances and that by May very few green bolls are available ; the disadvantages of the use of split bolls are considered in detail below. The ideal method, possibly, would be the use of bolls of a known age derived from tagged flowers, but the labour involved, especially in a year of high percentage shedding, precludes its use on a large scale.

The results of these estimates of damage are shown in figs. 11-15. It will be seen that there is a very close correlation between percentage staining and numbers of punctures on a boll, this being particularly marked towards the close of the season. It so happens, in fact, that percentage staining and number of punctures to a boll are numerically equal, at any rate in the lower part of their range of values. There is also a marked correlation, date for date, between stainer population and stainer activity, as measured by punctures per boll or percentage staining, where such estimates are based on green bolls (fig. 11, 1933). This is as one expected ; bolls of three weeks age should show pretty clearly the damage due to the population in the field at the time of collection, since bolls punctured up to one week old are usually shed, hence any bolls three weeks old showing puncturing, must have been infected during the fortnight preceding collection. The curves for the Cotton Experiment Station in 1932



and 1933 (figs. 11 and 12) are similar to each other, although the former was obtained from examination of green and the latter from examinations of split bolls. One must remember, however, that the green bolls were of large size and that a large proportion of them must have been approaching maturity.

Taking all those curves derived from mature or split bolls (fig. 11, 1932 and figs. 12-15), there is no very well marked relation between stainer population and stainer activity. This is due partly to the fact that estimates were made on mature bolls and thus represented a summation of the damage which had been done to the bolls throughout their life, and partly that population records for adults did not truly represent the population of effective vectors of disease, since late instars as well as adults puncture the bolls. The effects of these factors are first, to shift back the activity curves with respect to the population curves and secondly to superimpose on the curve for adult population the same curve shifted back two weeks, this being the time approximately taken in the fourth and fifth instars. If this is done a fairly close approximation of the curve for stainer activity and population of effective vectors is obtained. One has still, however, to take into account the fact that decreasing temperatures towards the end of the season differentially affect the maturation period of bolls, the growth rate of nymphs and the rate of spread of infection within the boll. Furthermore, damage is expressed as a percentage whilst the population is an absolute measurement, so that at the beginning and end of the season, when the number of available bolls is small and stainers are concentrated upon them, a high damage population ratio follows. All these factors tend still further to distort any relationship between the different curves.

Experiments in Transmission of Internal Boll Disease.

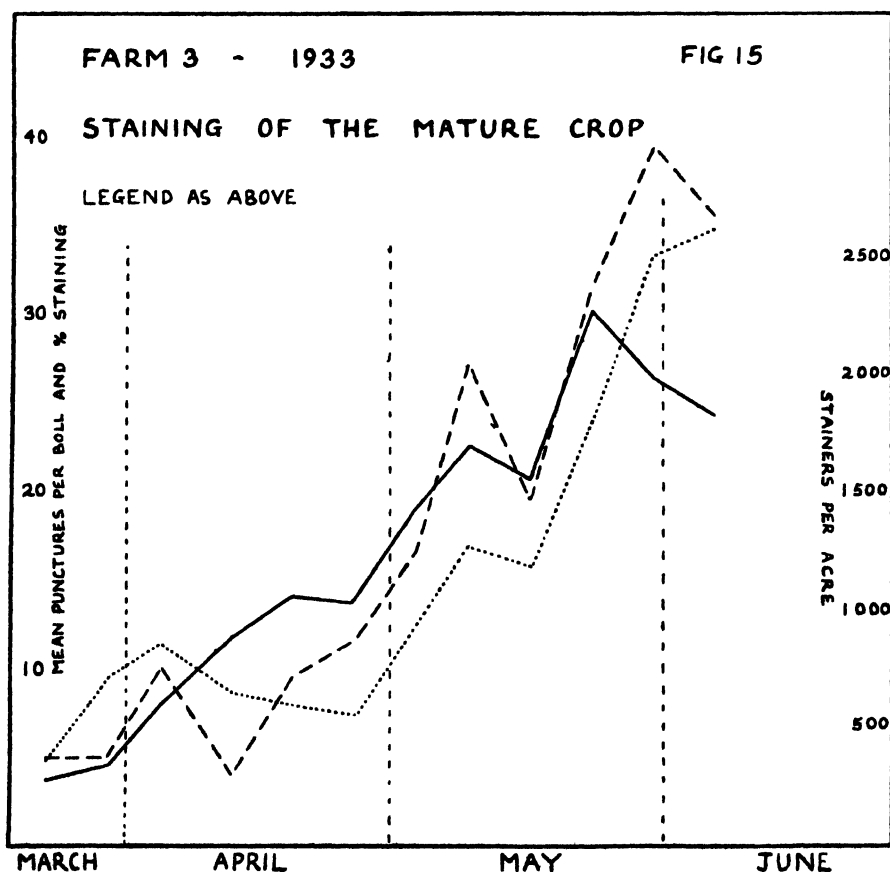
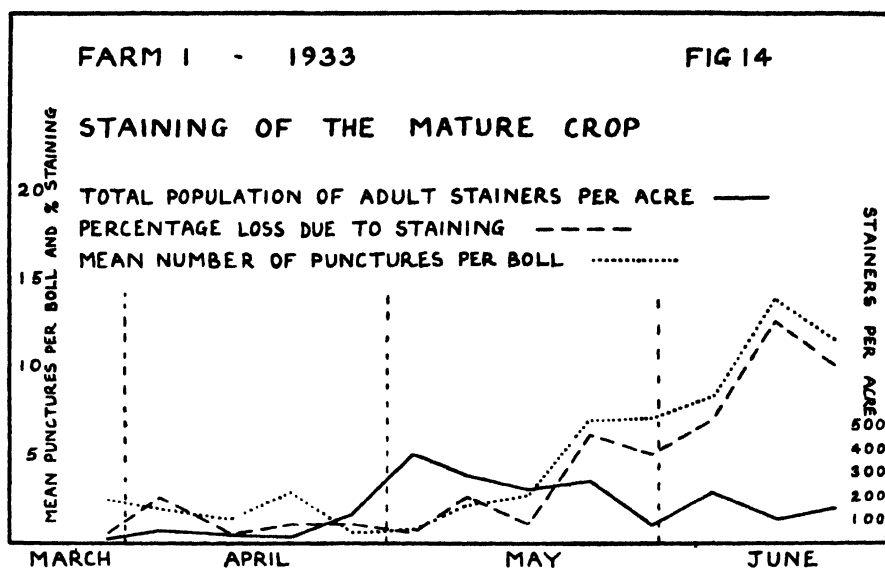
Arising chiefly out of the points raised in the attempt to correlate stainer population with the amount of staining in the crop, a number of lines of investigation have been started, of which details are given below.

1. *Critical Age of Nymphs as Vectors of Internal Boll Disease.*

As mentioned above, it is important to know to what extent stainer nymphs are capable of transmitting disease. The first requirement of an efficient vector is that it should be physically capable of penetrating the boll wall with its stylets. Experiments have therefore been carried out in which second instar nymphs of *D. nigrofasciatus* were fed on unopened bolls of four grades or size, ranging from 1.0-3.5 cm. diameter. *D. nigrofasciatus* was chosen because it has shorter stylets than either of the other species, and it was assumed that if it was successful, the others would be also. The rostra of all nymphs that died or of the exuviae of those that moulted were measured, and a separate series of measurements was made to determine the thickness of the carpel wall of the bolls on which the nymphs were fed.

The measurements showed that for second instar nymphs and hence for all older nymphs, stylet length is greater than boll wall thickness. Actually, however, the mortality was very high amongst nymphs fed on either very small or nearly full-grown bolls, whilst on half-grown bolls the majority of the second instar nymphs moulted.

A subsidiary experiment, in which nymphs were fed on bolls of the same size grades, but split open so as to eliminate any possibility of mortality due to inability to penetrate, showed that the failure of nymphs to survive on small unopened bolls is due to inadequate nourishment. There was a progressive decrease in mortality, and in length of stadium of those which moulted, nymphs fed on a series of bolls of increasing size. The mortality amongst nymphs fed on unopened bolls of large size must therefore be due to difficulty in getting at the food. It is frequently seen that nymphs feed with the first and second (basal) joints of the rostrum projecting backwards and the stylets sliding in the third and fourth (distal) joints. In such cases



the effective stylet length is reduced by the length of these two distal joints. As possibly the added support is necessary when attacking harder walled bolls, this may explain the difficulty in penetrating older bolls.

It thus appears that whilst second instar nymphs of *D. nigrofasciatus* have stylets long enough to penetrate the wall of bolls of any size, in actual fact the amount of feeding that takes place on unopened bolls is small, as it is only within narrow limits (bolls 2.0–3.0 cm. diameter) that they can obtain proper nutrition, bolls smaller than this being deficient in essential foods and bolls larger than this being difficult to penetrate, possibly because the full stylet length cannot be used.

A similar state of affairs was the case with third instars fed on the same grades of boll size, the mortality being high and the stadium prolonged on bolls of the smallest and largest sizes. Not until the fourth instar was reached did nymphs thrive satisfactorily upon unopened bolls. One may infer that it is not until this stage is reached that the nymphs become a serious factor in the spread of the disease.

A further important fact is that a diet of unopened bolls leads, in general, to a high mortality with prolongation of the stadia. It therefore follows that should eggs be laid in the field before open bolls are available for food, the green bolls, whilst producing only a very small F_1 may, by their very retarding action, suffice to tide over a small nymphal population until open bolls are available.

2. Internal Boll Disease due to Causes other than *Nematospora* spp.

As stated in the introductory note, staining of unopened bolls sometimes occurs in the absence of either *Nematospora* or of stainers. This was first noticed in the ratoon crop in November–December 1931, when a considerable amount of staining of unopened bolls as observed before stainers had come into the crop and was correlated with the presence of a number of Pentatomids, notably *Piezodorus purus*, Stål. Observations were continued in the ratoon crop in December 1932, but unfortunately the insect population was small and very little staining occurred. Such as did was again correlated with puncturing and a number of species of Pentatomids were again prominent, but microscopical examinations in both years revealed no signs of *Nematospora*. Inoculation of sterile bolls, i.e., bolls bagged as flowers, by *Piezodorus purus* resulted in heavy bacterial infection and staining following puncturing. A somewhat similar state of affairs existed in the early part of the 1933–34 season on plant cotton, when *Nematospora* was extremely difficult to find in stained bolls. These on culturing and microscopical examination revealed bacterial infections. Similar infections were obtained by pricking sterile bolls with a sterilised needle and exposing them to the air, bagged with muslin to prevent the access of insects.

It seems probable that in the early part of the season when conditions are more humid, internal boll disease is due, to a considerable extent, to bacterial infection present on the boll surface and carried inside through insect punctures.

3. Transmission of *Nematospora* spp. by Stainers.

Stainers collected on wild host-plants in the early summer, before the migration to the crop has occurred, were tested on sterile bolls with the following results.

Species	Wild Host	Date	<i>N. gossypii</i>	Bacteria
<i>D. nigrofasciatus</i> adults ...	Wild Cotton (<i>G. herbaceum</i> var. <i>africanum</i>)	November and December	X	X
do.	<i>Hibiscus vitifolius</i> ...	December	X	X
<i>D. intermedius</i> adults ...	<i>Hibiscus</i> sp. ...	January	X	—
do.	<i>Sterculia rogersii</i> ...	November and December	X	X
<i>D. intermedius</i> nymphs ...	<i>Sterculia rogersii</i> ...	January	—	X

The above observations were made in 1932-33, when stainers were scarce in the veld. They serve to indicate that stainers probably carry the infection with them when they migrate into the cotton crop; they are being amplified in the present season.

Later in the season the stainer population in cotton appears to become saturated with the disease. The following table gives the results of an experiment undertaken in late May 1933, in which four adults of each of the three species of stainers were caged on each of a number of sterile bolls.

Species	No. of Bolls punctured and infected					No. of bolls punctured but not infected	Total Bolls
	<i>N. gossypii</i> alone	<i>N. gossypii</i> + bacteria	<i>N. gossypii</i> + other organisms	Bacteria alone	Other organisms alone		
<i>D. fasciatus</i>	6	1	1	2	—	3	13
<i>D. nigrofasciatus</i>	8	5	—	1	2	—	16
<i>D. intermedius</i>	12	2	1	—	—	—	15
Total	26	8	2	3	2	3	44

Evidently all three separate species of stainer are capable of transmitting the disease. The situation differs markedly from that in the early part of the season when *Nematospora* was difficult to find.

The bulk of the infection in the crop appears to be due to the species *N. gossypii*. No detailed periodical examinations were made in 1933 to determine the relative abundance of *N. gossypii* and *N. coryli*, but the latter only appeared infrequently in cultures.

Course of Infection in the Boll.

The course of infection in the boll has been followed in several experiments in which sterile bolls have been artificially infected either by caging stainers on them or by injecting, with an hypodermic syringe, a suspension of the fungus derived from culture media. The medium used in all these experiments has been potato-dextrose agar.

1. Inoculations with Stainers, 1932.

Males and females of *D. fasciatus* collected in the crop were separately caged for 2 days on bolls of four age groups: 10-25-40-55 days. Each group was examined in three lots, 5-10-15 days after inoculation.

The number of punctures per stainer did not vary greatly, being of the order of 0.5 to 1.0 per stainer per day. The female stainers, were, however, in all cases more effective than the males, giving about 40 per cent. more punctures. Puncturing appears to be more or less at random over the whole boll surface, with the exception that there are slightly more along the lines of carpel divisions than elsewhere, these frequently giving rise to proliferations.

It was very noticeable that the characteristic proliferations associated with puncturing only developed in bolls up to four weeks of age when punctured and that those in the stage of very rapid growth (10 days old) developed the greatest

percentage of proliferated punctures. The proliferation evidently occurs within the first five days following puncturing, for there was little difference in the amount of proliferation in bolls examined at intervals of 5–10–15 days after exposure to stainers.

The infection appeared to spread more rapidly in bolls which had reached the stage where rapid growth had ceased and lint thickening was in progress (4–8 weeks) and less rapidly on both bolls which are in the very rapid growth stage (0–4 weeks) and bolls which are beginning to mature, dry out and split (8–10 weeks). This is what would be expected on physiological grounds. The intensity of infection increases regularly with the incubation period up to 15 days, beyond which it was not followed.

The above observations were carried out before any facilities were available for mycological work and the organisms present probably included bacteria. As the experiment was performed in the latter part of the season, however, it is probable that the bulk of the infection was due to *Nematospora*.

2. Inoculations with Stainers, 1933.

A series of inoculations was made in this season by caging adults of all three species of stainer for two days on sterile bolls. Details of the infections produced by the different species have been given above. The bolls were late season bolls infected when four weeks old and were examined in two groups, 10 days and 30 days after infection. Every infected point was examined microscopically to determine the causative agency.

It appears that in the early stages of infection (10 days after inoculation) *N. gossypii* is limited to hyphae and sporangia produced near the point of inoculation. Where a puncture has actually penetrated a seed, the interior of the latter breaks down completely and there is some proliferation of the inner and outer epidermis. The lint hairs produced from this seed are discoloured, but there are no signs of the fungus beyond the actual point of inoculation. In cases where a puncture has not penetrated the seed, the lint hairs are discoloured, but not so extensively with the presence of the fungus and there is no penetration by the fungus of the seed.

In the later stage of infection (30 days after inoculation) the fungus appears chiefly in the form of free spores, sometimes singly, usually in bundles more or less loosely held together by their appendages. Such mycelial development as remains consists of short hyphal lengths and fragments of burst sporangia. The loose spores are distributed throughout the lock, usually beyond the region actually stained.

3. Inoculations with Fungus Suspensions, 1933.

In order to obtain a clearer picture of the course of infection, a number of inoculations were made by injecting 0.2 cc. of a suspension in sterile water, derived from actively growing mycelium on potato-dextrose agar slopes, into sterile bolls. Both species of *Nematospora* were used, the original isolations having been made from cotton bolls selected on the Cotton Experiment Station earlier in the season. The bolls were four weeks old when inoculated.

N. coryli, Peglion :—Bolls examined one week after inoculation showed the staining to be due to the coagulation and yellowing of the granular protoplasm of the lumen of the lint hair, which at this age is not yet vacuolated. Staining extended over about half the lock. The fungus was found in every case where staining developed, but localised, usually adjacent to the seed coat but not penetrating it, actively producing sporangia, with a good deal of hyphal development. Yeast-like cells were rare.

Bolls examined three weeks after inoculation showed a large increase in the stained area, which covered the greater part of the lock, the lint being to some

extent matted on the surface of the seeds, giving a kidney-like effect. The fungus was largely present in the form of spores and their distribution was definitely coincident with that of the staining.

N. gossypii, Ashby & Nowell :—Bolls examined one week after inoculation showed a marked difference from those infected with *N. coryli*. Within the infected locks the lint was a dirty, yellowish colour, matted on to the seeds, giving a pronounced kidney effect, while the seed coat was stained brown in spots. The fungus, however, was extremely difficult to find, except actually on the line of puncture or within a seed which had been pierced by the needle, in which cases it occurred as hyphae, breaking up into chains of sporangia, and as free spores.

In bolls examined three weeks after inoculation these conditions were intensified, the locks being totally stained and the lint reduced to a papery membrane closely adpressed to the seeds. The fungus was extremely difficult to find, only occurring adjacent to the point of inoculation, or within a penetrated seed, in the form of free spores and mycelial fragments.

In none of the above cases did the infection extend beyond the lock actually injected, nor was there any penetration of the interior of the seed by the fungus or the staining, except where the seed had been actually punctured by the needle. From these results *N. gossypii* appeared to be a much more virulent organism than *N. coryli* and the extension of the damage so far beyond the point of occurrence of the fungus suggested that the staining might be due to a toxin set up by the organism. In order to test this, a further series of inoculations were performed, using 6 week old bolls and three treatments :—

- i. Inoculation of 0.2 cc. sterile water.
- ii. Inoculation of 0.2 cc. spore suspension from actively growing mycelium on potato-dextrose agar.
- iii. Inoculation of 0.2 cc. of sterile extract prepared by centrifuging a spore suspension and autoclaving the supernatant liquid.

The inoculated bolls were examined 1 and 3 weeks afterwards with the following results :—

Sterile water :—Occasional slight discolorations of the seed occurred where the needle penetrated, otherwise there was no effect.

N. coryli, living spore suspension :—After one week there was an irregular light yellow stain localised near the point of inoculation, with no matting or kidney effect. The fungus was coextensive with the stained areas and occurred in the form of free spores and sporangia with considerable hyphal development. After three weeks the staining was heavier, well marked down the line of suture of the boll, with very little matting or kidney effect and in colour bright yellow. The fungus was generally distributed throughout the lock in the form of spores, sporangia and short hyphae.

N. gossypii, living spore suspension :—Staining was heavier than with *N. coryli*, but with only slight matting of lint or kidney effect and it was most prominent round the suture line and adjacent to the carpel wall. The fungus was not coextensive with the stained area in bolls examined after one week, though after three weeks free spores were distributed throughout the lock.

In the case of both species of *Nematospora* the staining was much lighter in bolls inoculated at six weeks of age than in bolls inoculated at four weeks of age.

N. coryli, sterilised extract :—After one week a very slight, almost negligible stain was visible, closely associated with the point of inoculation and to some extent down the suture line. After three weeks the staining was moderate but patchy, severest at the base of the lint hairs and down the suture line.

N. gossypii, sterilised extract :—After one week bolls were heavily stained, especially on the suture line and against the carpel wall, the lint breaking down to a dirty yellow colour with slight tendency to matting and kidney effects. After 3 weeks this condition was intensified, with definite kidney effect. There was no penetration of the seed but some discoloration of the outer epidermis, this possibly being connected with the deeper staining at the base of lint hairs.

The above observations suggest that staining is due to the coagulation and post-mortem discoloration of the protoplasmic contents of the lint hair following death due to a toxin liberated by the actively growing mycelium of the fungus. This toxin is more virulent, or is liberated in larger quantities, in the case of *N. gossypii* than in that of *N. coryli*. The decreasing susceptibility of bolls to staining as they approach maturity may thus be due partly to the evacuation of the lint hairs and partly to the drying out of the boll content impeding the movements of fluid toxic substances. It is noticeable that staining is more pronounced along the carpel wall and the line of suture of the carpels, which are the natural channels along which any liquid within the boll might move.

Summary.

Records of stainer infestation in cotton have been taken at the Cotton Experiment Station, Barberton, South Africa, since 1931, and in 1933 a uniform system of recording stainer populations in cotton by sampling 10-acre blocks was extended to four farms in the Barberton district, three farms in Swaziland and the Cotton Experiment Station at Magut, Natal.

The records so obtained show that stainers normally appear in plant cotton in late February or early March. *D. intermedius*, Dist., is present in comparatively small numbers throughout the season ; *D. nigrofasciatus*, Stål, and *D. fasciatus*, Sign., are very variable in relative abundance. In 1933 the latter species was practically absent from cotton at all points save those in the vicinity of ratoon or standover cotton, but in 1931 and 1932 it appeared in numbers equal to those of *D. nigrofasciatus* and bred up a very much larger population in the crop.

Where normal migration occurs, all three species of stainers pass through two and a partial third generation in the crop ; at the end of the season part of the adults migrate from the crop and the remainder, together with the bulk of the nymphs, may be destroyed by appropriate clean-up measures.

Extensive surveys of the Transvaal Low Veld and rapid tours of portions of Swaziland, Zululand and Portuguese East Africa, indicate that the principal wild food-plants of stainers in these regions comprise the genera *Abutilon*, *Gossypium*, *Hibiscus* and *Sida* in the Malvaceae, *Melhania* and *Sterculia* in the Sterculiaceae and *Adansonia* in the Bombaceae.

The Malvaceous host plants and *Melhania* are all herbaceous or shrubby species and upon these *D. nigrofasciatus* is frequently found. It is possible that colonies of these plants existing in sheltered situations may provide overwintering grounds for this species.

Two species of *Sterculia* are known, *S. rogersii* and *S. murex*. The former is widespread and abundant throughout the Low Veld and probably constitutes the main breeding-ground of all species in the early summer. The latter species is rarer, and its status as a food-plant is not yet fully investigated.

The Baobab occurs in large numbers in the Northern Transvaal, but it has not yet been proved to be a winter food-plant. The latest information shows that during the summer it may commonly be infested with *D. fasciatus*.

In conjunction with stainer population records in the crop, weekly systematic records of damage to the crop have been obtained from samples of bolls which have

been examined for puncturing and graded for degree of staining. The number of punctures per boll and the percentage staining are strongly correlated, but it has proved difficult to correlate these with stainer population, except where young bolls are examined.

Internal boll disease, particularly early in the season, may be due to bacterial organisms transmitted by species of Hemiptera other than stainers. Later in the season the infection of the crop is more definitely due to *Nematospora* spp., of which *N. gossypii* is commoner than *N. coryli*.

All species of stainers collected on cotton have been found to transmit *Nematospora*, though they are not efficient vectors until the fourth instar is reached. Adult stainers collected on wild food-plants (*Gossypium herbaceum* var. *africanum*, *Hibiscus* spp., and *Sterculia rogersii*) have been shown to be infected with *N. gossypii*.

The etiology of the disease produced by both species of *Nematospora* has been followed in inoculation experiments, using pure cultures. The rate of spread of the disease varies with the age of the boll at the time of inoculation, being slower when the boll has passed middle age. In neither species does staining extend beyond the focus in which infection starts, nor does the fungus occur within the seed except following direct puncturing of the seed.

The fact that the staining is not co-extensive with the region occupied by the fungus, but goes far beyond it, and that a pathological condition indistinguishable from that due to the living organism may be produced by injecting a sterilised suspension of the fungus, suggests that the death of the lint hairs, producing staining, is due to a toxic substance liberated by the developing fungus.



Sterculia rogersii, wild food plant of *Dysdercus* spp.

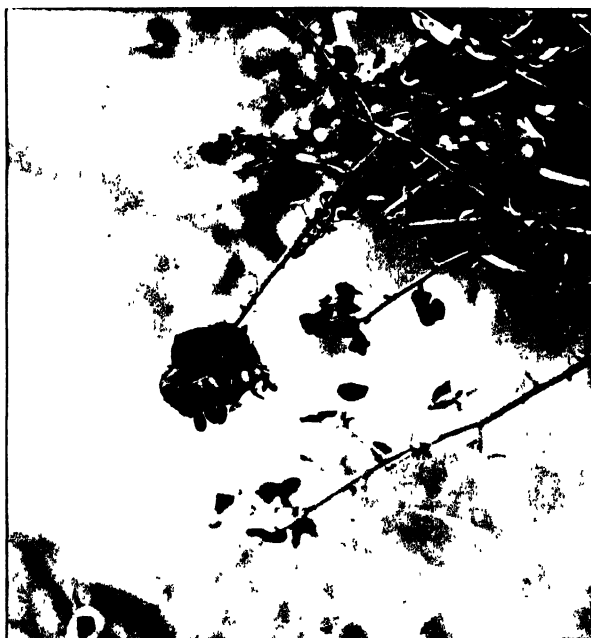


Fig. 1



Fig. 2.

Fifth instar nymphs of *Dysdercus intermedius* feeding in capsules of *S. rogersii*.

PROTECTION OF VEGETATION AGAINST GRASS-FIRES AS A POSSIBLE SOLUTION FOR SOME TSETSE PROBLEMS.

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(PLATES XIV-XVII.)

1. Introduction.

Experiments by the writer at Chirinda in Southern Rhodesia from 1905 onward in burning the grass in different months and in keeping it unburned showed that the savannah communities dominated by *Berlinia-Brachystegia-Uapaca*, *Acacia natalitia*, *Parinarium curatellaefolium* and *Pterocarpus mellifera*, respectively, were each, under the conditions obtaining, merely a vegetational sub-climax, and that the factor which inhibited the advance of the vegetational succession to its natural climax was the annual grass-fires. Under the high rainfall occurring there deciduous thicket first followed the cessation of the fires away from the neighbourhood of rain forest (Pl. xiv, figs. 1, 2, and Swynnerton 1921a), but the latter was the ultimate climax.

In 1925 it was found by Swedi Abdalla, our head fly-boy, and confirmed by Messrs. W. H. Potts and B. D. Burt, and Dr. G. B. Wallace, that even the relatively low deciduous thicket of the Central Province of Tanganyika tended strongly to exclude *Glossina morsitans*. The decision was at once taken (in view of the Rhodesian results and much observational corroboration in Tanganyika) to test the possibility of reproducing these inimical conditions (a) by advancing the natural vegetational succession by not burning the grass, (b) by cheap or remunerative planting. An Ecologist and a trained Forest Officer were, with others, added to the staff of the Tsetse Research Department and arrived late in 1927.

Dr. J. V. Phillips, the very efficient Ecologist, laid out a number of small plots, with instruments and controls, in the various vegetational communities at Kikore and also with Mr. G. W. St. Clair-Thompson, at Itundwe, early in 1929, to test the succession as affected by the exclusion of fire and game respectively. Dr. J. D. Scott (our former Research Botanist) has recently published a particularly excellent description of part of the work done (Scott, 1934). In the same year (1929) the writer inaugurated our first fairly large-scale test of the indirect effect on the tsetse itself of the exclusion of the grass-fires by demarcating in Shinyanga a strip to be kept unburned as an experimental barrier against *G. swynnertoni*.

2. Experiments on *Glossina swynnertoni* and *G. pallidipes* at Shinyanga.

A.—The Experiments.

(1) The Mantine Road Thicket Barrier is the strip just referred to. It is 300 yards wide by 1,360 long and is continued for a further $1\frac{1}{4}$ miles in the form of a planted experimental evergreen barrier of *Euphorbia tirucalli* one hundred yards wide. These combined lengths divide the area designated as Block 4A from 4B (see fig. 1).

(2) In 1930 a block of four square miles (Block 4A) and a further future thicket barrier (on the old Mwanza Road) were added to the country to be kept unburned to test the effect on the vegetation and the tsetse of the release of the succession thereby.

(3) Block 10A, now only two miles square but very specially favourable in character to *G. swynnertoni*, was added a year later still.

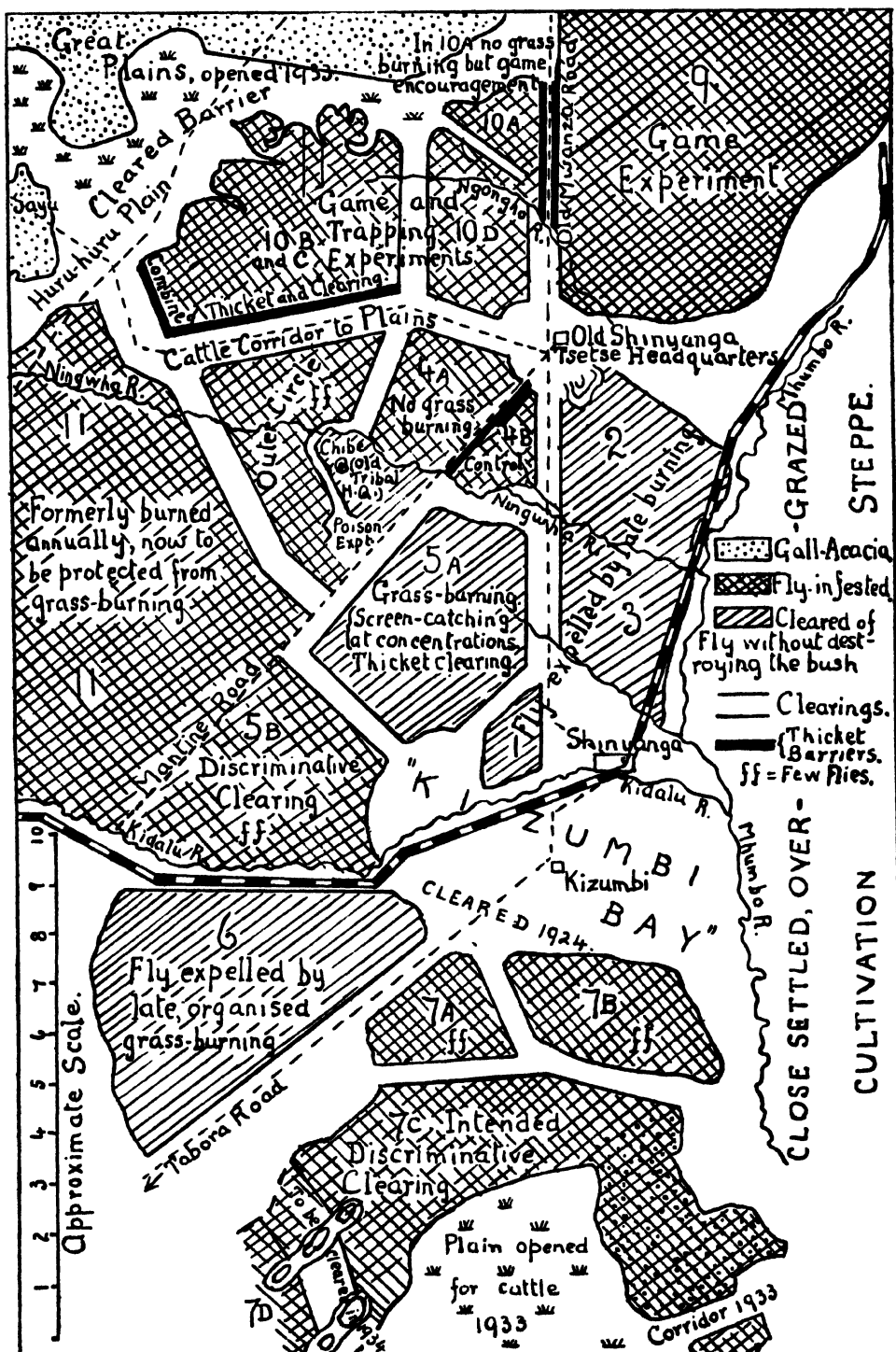
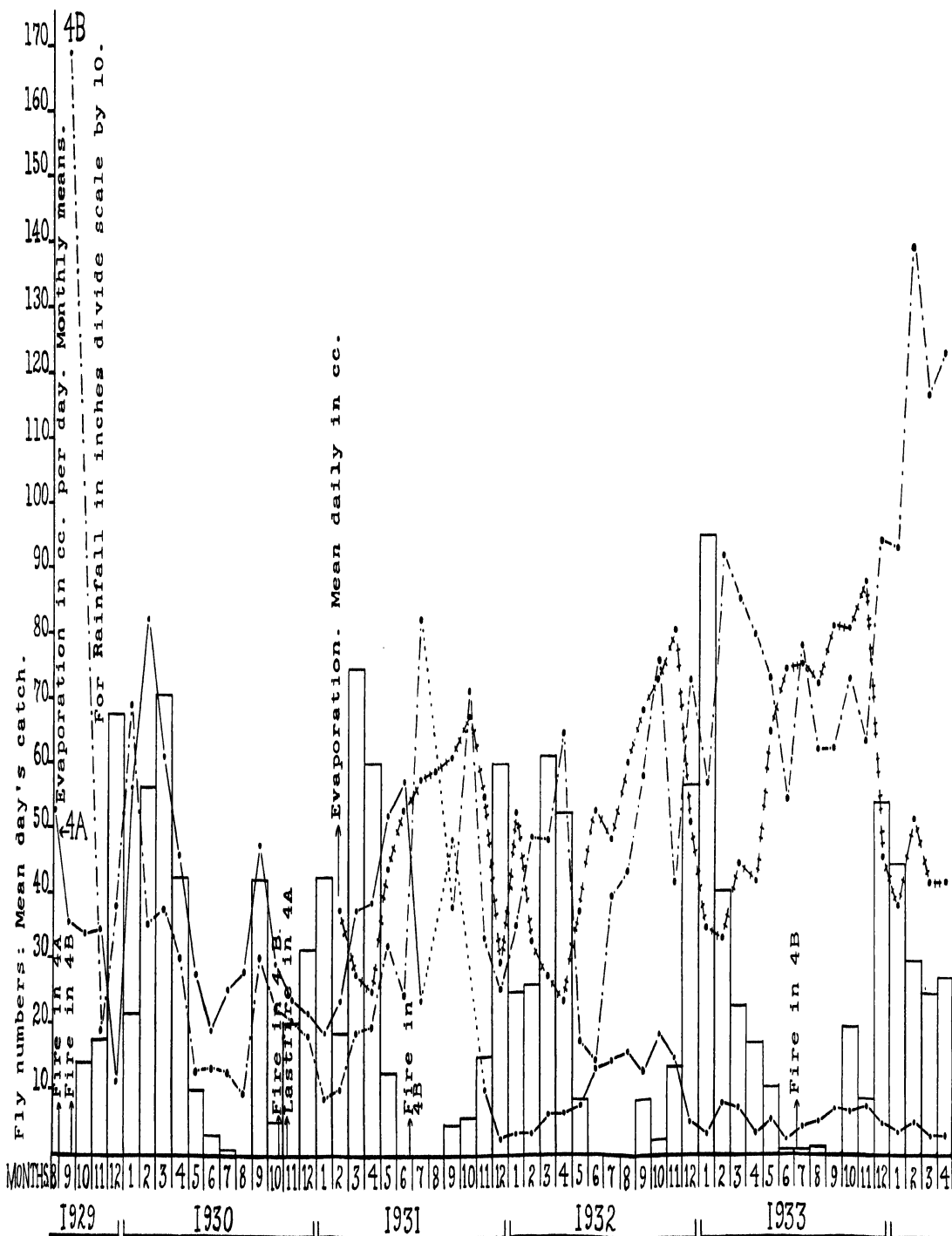


Fig. 1. The Experimental Tsetse Campaign in Shinyanga.



Graph to illustrate the course of events in 4A and 4B.

Notes—1. The Rainfall figures used were those of Ibadakule, 8 miles away, until January 1931 inclusive.

2. After January 1931 rainfall and evaporation figures are those of the open station, Shinyanga, 2 miles from the centre of 4A and 4B respectively.

3. The fires of 1929 were fierce. The subsequent fires were lighted in such a way as to be mild.

(4) The first (Mantine Road) thicket barrier has now (in May 1934) missed four burnings, 4A and the second (Mwanza Road) barrier three burnings, and 10A two. In 1930 Blocks 5A and 11 were unburned for that one year only.

The control to 4A and to the Mantine Road Barrier is 4B, alongside, and that to 10A and the Mwanza Road Barrier for the present is Block 9, also contiguous, though 4B is a useful match for them. The controls are burned annually, native-fashion. Aerial photographic mosaics and other botanical maps have been made of the blocks to record their early conditions and will be repeated ultimately. The Entomologist stationed at Shinyanga carries out fly-rounds every fortnight.

B.—*The Effect on the Vegetation of not Burning.*

The Mantine Road thicket barrier (on granite and schist) has become a nearly continuous thicket from eight to ten feet high (Pl. xvi, fig. 2). Blocks 4A and 10A are still largely grass country but thicket is growing up everywhere (Pls. xv, fig. 1; xvi, figs. 1, 3; xvii, fig. 1). Those areas particularly that are characterised by hardpan and its equivalents, and which were the concentrating points for large numbers of *G. swynnertonii*, are becoming overgrown or hemmed in very extensively with a close growth of the shrubs *Dichrostachys glomerata* and *Ormocarpum trichocarpum*.

A mat of dry rotted grass (Pl. xvii, fig. 2), varying as to its presence, absence and amount with its original bulk and the subsequent action of the termites, carpets the ground between the last season's grass-stems. In 4A at least the grasses that cover the old concentration centres are for the most part longer and closer than they were.

A tendency towards homogeneity is fast replacing the old sharp division between thicket, savannah wooding and opener concentration grounds—each of which played an important rôle in the daily and seasonal life of the tsetse. Soon, for practical purposes, the fly will have thicket only.

C.—*The Effect on the Game.*

There seems to have been very little effect on game. There are fewer impala than formerly in 4A, but there are about 25 giraffe, numbers of wart-hog, some steinbuck and duiker, and many dikdik; half a dozen greater kudu are present, and roan and eland frequent the block. Reed-buck and bush-buck have been noted. The game of all species seen here in a walk of 1,000 yards has increased by nearly a third in three years despite the greatly decreased visibility. In Block 4B, the control, the visibility is far better and therefore probably nearly three times the amount of game could be seen in a thousand yards, but no increase in that number has taken place in the three years. A recent study of this block by Commander D. E. Blunt has shown that it contained at that time no more total game than 4A, although many more impala; there is, however, much interchange, and additional impala come in from Block 3. Block 10A has much permanent game in the shape of wart-hog, impala, duiker, dikdik, a few bush-pig and one or two bush-buck and reed-buck; a rhinoceros cow and a calf visit it, and game in large numbers from the plain on the north wander in and out of the block or make stays in it, such as giraffe, zebra, eland and additional impala; lions drink at the dam.

D.—*The Effect on the Tsetse.*

The thicket barriers are as yet by no means completely effective, but the flies on the roads they serve, formerly sufficiently numerous to be a serious nuisance, are now but few. In 4A the fly population showed its first apparent response to the measure by a failure to recover with the usual bound early in the second short dry season (1931/32) that followed the last burning (1930). This lack of resilience has characterised its curve ever since (fig. 2). Usually in dry periods a small gradual upward trend can be seen, in contrast to a retrogression in wet months—though part is doubtless an "activity" effect. The curve in 4A reached its lowest points in December

1931 and in April and June 1933 ; since these last it has run fairly level and very low. In March of this year (1934), the fly density, as gauged by the weekly fly-rounds, averaged only one-fifteenth of the numbers it averaged in the fly-rounds of March 1930. On the latter rounds from 10 to 25 flies used to be taken in passing certain concentration sites, and in one of these sites H. M. Lloyd, in the course of marking experiments in January–February 1931, used to take from 40 to 50 flies in an hour. Now, at any of those sites, two is a rare catch ; one or none is more usual. In contrast to all this, in the control block, 4B (in which before 1930, as in 4A, the flies had been under attack by late grass-fires), despite its small size (1½ sq. miles), the number of flies has shown a sustained and strong tendency to rise since natural conditions were restored.

It has only been possible to start fly-rounds this year in 10A, but flies were definitely and always observed to be abundant there before grass-burning was stopped.

March					No. of rounds	Total flies caught	Flies per round (average)	Flies in 1,000 yds. (average)
4A	{	1930	...	...	5	312	62.4	11.2
		1934	...	...	4	17	4.2	0.8
4B (control)	{	1930	...	...	5	192	38.4	4.6
		1934	...	...	4	476	119.0	14.4
10A		1934	...	...	10	92	9.2	1.0
9		1934	...	...	10	567	56.7	9.4

March has been chosen to obtain a comparison with 10A, but the following table gives comparative figures for two six-monthly periods as between 4A and 4B only.

November to April					No. of rounds	Total flies caught	Flies per round (average)	Flies in 1,000 yds. (average)
4A	{	1929/30	...	...	17	890	52.3	9.4
		1933/34	...	...	23	124	5.4	1.0
4B (control)	{	1929/30	...	...	18	625	34.7	4.2
		1933/34	...	...	23	2,492	108.4	13.1

After one year without burning Blocks 5A and 11 both showed a reduction of density during the wet months. Other measures then supervened in the case of 5A ; in 11 the numbers of the fly rose again with the advent of dry season conditions.

E.—Discussion of the Results.

There can be no suspicion of 4A having been nearly freed of fly merely by the upgrowth of a barrier between it and 4B, for the barrier is only commencing to be markedly operative now, while the fly numbers have kept down for a year and were falling before that. From July to December 1931 indication of exchanges took place ; the fall in 4A in July was balanced by an equivalent rise in 4B, where a slow-burning night fire had improved conditions for the tsetse. The later effects of the

fire perhaps drove flies back to 4A in August–September, and they flowed back into 4B in October after rain. A simultaneous fall took place in both blocks in November–December, in 4A to the lowest point reached. After this, in 4B the fly recovered its numbers in the short dry season and has never really decreased, while in 4A, after a slight rise at first, the numbers settled down to a continuous decline.

This decline has certainly been due to the exclusion of grass-fires. The effect might have come about more rapidly than it would have in 4B (for example) through the fact that 4A has less hard-pan. But 10A, which has plenty, is now after two years without burning almost as low as 4A. Block 4A itself for seventeen months (February 1930–June 1931) maintained a fly population that was consistently higher than that of 4B and thus showed its original suitability as a well-balanced habitat—which was obvious to an observer in any case. Further, the vegetational conditions are visibly becoming adverse over increasing areas wherever the fires have been stopped.

The small population now in 4A would seem (in an environment that has no longer great seasonal vicissitudes and is already partly adverse otherwise) to have struck for the time being a nearly stationary balance at a low density, loss by emigration, deaths, and restriction of breeding about equalling increase. Were this an agricultural pest our task would be finished. As it is an insect the complete extermination of which is demanded, we must continue to watch till the growing "resistance" of the environment has become fully inhibitive to its existence. The present balance has probably been attained mainly by a process we had observed elsewhere already under our measures of reduction and which in some tracts occurs seasonally also—close concentration of the survivors in only the most favourable spots—though the converse of the factors that help to bring about balance at the high end of the density scale will have assisted. These (at the high end) may include the greater numbers of males that will assault each female when the population is great and so perhaps cause much abortion (Lamborn, 1915; Nash, 1930), greater special attention by birds and other enemies when it is worth their while (Swynnerton, 1921b), and (in extreme cases) the driving of the pestered game animals to live more in the open; also the converse of the first factor mentioned, namely the greater diffusion of the fly-population through good and less perfect habitats that was notable in the great fly-populations of Shinyanga when the writer first came there. Mere constancy of the season (Nash, 1933, p. 117) could not by itself produce balance (Nicholson, 1933).

Detailed observations and experiments now in hand will be discussed in a later and fuller collaborative paper. Meantime the following may be said as to the possible reason for emigration, deaths or hindrance to breeding that has brought the situation about or may influence matters in the future:—

(a) This is not lack of game, for the latter remains plentiful and the flies have at no time shown heightening of hunger or of female percentage as compared with those in the controls. They have continued well fed and seemed perfectly normal.

(b) The factor sought is unlikely, yet, to have been low visibility of food; the small buck have been much hidden (from man), but it would seem from the lack of hunger that the discoverable animals must have sufficed for the flies that have remained in the blocks. Relatively, however, game is much more visible in 4B, especially in the months after grass-burning, and this may have influenced migration from 4A, which is unburned.

(c) Tsetses settle habitually on bare ground and rock and log surfaces (now greatly masked by grass, etc.), and on standing tree-trunks; there and on animals the sexes meet. Reduced inter-discovery of the sexes might conceivably come about through the masking of the ground and the logs, by grass, though the tree-trunks are left.

(d) The factors concerned appear to be more operative in times of rain—in the blocks unburnt but not in the controls. This suggests that the reduction of the fly may be due partly or chiefly to the added and more sustained low-sited humidity that would result, firstly, from the fuller vegetational growth and shade and the wet mulch of old grass (Pl. xvii, fig. 2) that keeps the ground wet between showers—the more so when the rain is well distributed—and, secondly, from the further increase of soil moisture that would be consequent on these things indirectly, through the reduced run-off and better soakage. The resultant heightened humidity may affect the adults or pupae adversely (or some enemy favourably—as suggested by Vicars-Harris), or impair the breeding of the flies. A closely related point, which will be similarly seasonal in effect but is likely to come into play later, is the gradual confinement of the flies not into the best spots only, but also into quite inadequate patches and strips of their old habitat through up-growth of thicket between—deciduous thicket which they will enter and (if narrow enough) pass in the dry season but not in the wet, as two-years' special observations by Burt in the Kazikazi thickets showed clearly for *G. morsitans*.

(e) We can get yet closer to the incidence of the responsible factors. It is the conditions in the short rains that decide whether the fly population will be large or small during the short dry season and long rains. In each year and place in which the grass has been normally burned in country unsubjected to anti-tsetse measures, the conditions in the short rains have been so outstandingly favourable to breeding that the fly numbers, reduced just before to their annual very low minimum, have soared upward and reached a high point in the short dry season ensuing; from which point they may rise, run level or drop not very much. Nash's calendar of the seasons for *G. morsitans* (1933, p. 117) should be consulted also. Several things may contribute to bring the situation about :—

First as regards humidity : Frequent heavy showers; hunger cycle so lengthened that the risk of starvation is gone; a condition of short grass tufts with plenty of bare ground between, drying up quickly between showers, that is to say, drought relieved but humidity not excessive; and, owing to the ample presence both of good shade, lesser shade and dry sunlit surfaces, great ease for the flies to site themselves according to the humidity-need of the moment. Not humidity only, but readily *selectable* humidity, is the greatest boon brought by this season.

As regards other advantages : the continuance of the special facilities for a ground-settling insect to detect the other sex and the smallest food animals that characterise the later dry season; movement of game animals to the young grazing; rocks and logs highly visible; male percentage, and enemies also, probably relatively at their lowest, for with a population still small, the flies have begun to scatter.

All this must inevitably foster a strong "late spring" impetus to breeding.

In an unburned area the conditions are less severe during the late dry season. After that almost every advantage that burned ground affords is represented by a disadvantage in unburned areas. The ways in which humidity is increased have been touched on already. In addition, sooner or later, the visibility becomes worse and worse and (even more important) there is too much unavoidable shade, which is a disadvantage in the high humidity of the wet-season. Desertion by the flies of this type of area for the burned sites can be well understood, as can the probability that activity and breeding on the part of those that remain may be much handicapped. Actually, in an unburned area the density fails to rise appreciably with the short rains and short dry season and continues low, rising little or definitely falling, till the next relevant seasonal impetus arrives.

In 4A this impetus, in the form of the conditions that in favourable years cause an increase of the fly at the end of the rains, also seems weakened, but in Block 11 and at Kandaga (each in its first year of no burning) the density soared normally then.

The general rise at this time even in duly burned blocks takes place despite the visibility being reduced through long grass. This seems to throw the main stress on humidity, the lessening of which at the end of the rains, and especially of a poor rainy season, has improved matters—but it does not rule out lessened general visibility as an additional or subsidiary factor for an area that has gone far towards thicket, which is higher than grass.

(f) The careful and detailed observations carried out on plots burned and unburned for two years at Kikore by Scott and Burtt under the guidance of Phillips (Scott, 1934, p. 215) give us clues as to what actually is happening. Protection of the grass from fires produced in the soil a slight increase in organic matter, a heightened water-supplying power, a greater total water-content after the fires and in the early part of the rains, and a lowered temperature (very marked in the late dry season). In addition, there was lowered evaporation (the difference not so strongly marked in the rains but very marked in the late dry season) and reduced light-intensity. However, where the grass-cover became extremely dense, as happened in the *Acacia usambarensis* plots during the second season of high rainfall, evaporation from an atmometer six inches from the ground was "cut down to an absolute minimum."

In *G. swynnertoni* country a dense grass-cover is fairly general except in the special concentration grounds of the flies. In these the hard-pan of re-cemented decomposed rock that closely underlies the thin soil produces severe water-logging in the latter in heavy rain. Under the condition of non-burning the high, close grass and increasing thicket in the "semi-hardpan" soil flanking them, and in the cluvial country surrounding, must handicap or harm the tsetse in its alternative utilisation of these. Actually on the wetter hardpan soil of 10A there grew this last season in the early rains damp vernal-aestival societies of dense-packed and luscious herbaceous vegetation—*Aneilema*, *Commelina*, *Gladiolus*, *Lapeyrouisia*, a fleshy *Senecio* and others. It is interesting further, as regards both the lessened temperature and the lower evaporation rate, either of which might be expected to lessen fly-activity and so affect survival, and either of which, it is known, will affect reproduction, that it seems (as might be expected and as Vicars-Harris first noted) that the point in the evaporation above which fly-activity, fly-numbers or both, increase is higher in the unburned blocks than in the burned.

The foregoing offers merely a rough and still tentative and merely preliminary explanation of a position which will be discussed more precisely in a future publication. Something very far short of the vegetational climax of continuous dense thicket has brought it about, and the ecological observations at Kikore show that factors are actually brought into existence by not burning the grass which might produce this effect. As to what will be the main result of a near approach to the climax there can be little doubt. It will be, as suggested already (p. 417), the replacement of three vegetation types, at least two of which are vital to the tsetse in its daily and seasonal life, by (for practical purposes) a single type only—namely, thicket, with its concomitants of reduced visibility and excessive wet-season moisture and shade. It is believed that the effect of the beginning of the growth of this eliminative process is probably already being felt. It has been a source of surprise to the writer that merely the beginning should have produced so great an effect. The measure is succeeding so far in small pieces of country; we must now test it in larger areas.

3. Observations on *Glossina morsitans*.

The area of Dr. T. A. M. Nash's fly-round at Kandaga, in Kondoa-Irangi, was unburned in 1928 and, except for a few patches, in 1929 also. There was an unfortunate gap in the fly-rounds following the first omission to burn, and all that can be said is that it is suggested by what remains that the course may have been like that of Block 11 in Shinyanga. Certainly there was a normal rise at the end of the rains. In the second year there was a gradual and marked depression during the rains.

What would have been the effect of the advent of the second dry season is unknown, for in late April 1930 this round was subjected to the torrential spate which in varying degree swamped all the fly-rounds in the area and brought the populations down with a rush. Both this and the effect of not burning at Kandaga have been described by Nash himself (Nash, 1933, p. 120). *G. morsitans*, Potts suggests, is probably here approaching the wet limit of its range (still more nearly approached in Bukoba and in Ankole in Uganda), so that a relatively small increase in humidity may affect it more than it would elsewhere.

Is it likely, actually, that this form of biological control can be applied to *G. morsitans*? Firstly, *G. morsitans* can exist under more humid conditions than does *G. swynnertoni*. Secondly, *morsitans* country (*Berlinia-Brachystegia*, etc.) burns less fiercely than that of *G. swynnertoni*. Therefore the results of not burning may be expected to be less striking or more delayed. There are, for this purpose, three types of *morsitans* country. In one, on good soil or under a good rainfall, grasses and shrubs can compete with the grasping "Miombo" (*Berlinia-Brachystegia*) trees, and exclusion of fire does often produce thicket (Pl. xiv, fig. 2, and Swynnerton, 1921a); *Ostryoderris stuhlmannii* and other spp., as a habitat for *G. morsitans*, will come into the same category. In another type (Central Province, Tanganyika) there is little or no grass or regeneration and little prospect of producing an early alteration under the actual "Miombo" wooding; not burning in the nearly grassless Singida country is not stopping a fly advance; *Copaifera mopane* wooding also comes into this category. In a third, which is much more prevalent than either and which covers our Western Province, the conditions are intermediate. The first and the third are well worth experimenting with, especially seeing (a) that it appears to take less than advancement of the succession to thicket to produce considerable effect on *G. swynnertoni* at least; (b) that some effect was seen to have been produced on *G. morsitans* quite quickly in not too promising country by Nash in Kandaga, Central Province—in the wet months (Nash, 1933, p. 120); (c) that, as with *swynnertoni* and hard-pan, so with *morsitans* and its feeding-grounds and seasonal foci, it may suffice as regards visibility, if these chiefly should densify (Swynnerton, planting of vleis, 1921c); this the feeding grounds will often do relatively quickly; (d) that of the many *morsitans* areas in different colonies known to the writer, there is not one of which great parts or the whole are not burned through annually by the fires; for *morsitans* is always an associate of pyrophytic communities, and from the changes, slow or more rapid, which are bound to occur as the result of stopping the fires, it may go or only continue to exist precariously.

At Itundwe, in the Kondoa-Irangi District, the *Berlinia-Brachystegia* wooding is of one of the types referred to above as "intermediate." It is at present fairly infested with *G. morsitans* as the probable result of two poor rainy seasons in succession. A small piece of this *Berlinia-Brachystegia* country, one and a third miles long by a third of a mile broad, was demarcated for his experiments by Mr. St. Clair-Thompson in 1929 and, except for one plot within it, has been kept unburned by us since; it has thus missed five burnings. Near it is a further small piece of country that each year has been burned rather patchily and last year was burned not at all. The protected area has thickened up greatly and remarkably evenly, except for one rather large corner, and the density of the woody vegetation resulting is such as in our general experience is unfavourable to *G. morsitans* in the wet season particularly, although it is less than dense thicket. The patchily-burned country has thickened up also, but unevenly.

A joint investigation of the area just carried out by Dr. Jackson and the writer has confirmed the fact, noted in previous examinations of it, that the shrub that has produced most of the densification between the trees is a large, woody *Indigofera*. An *Acalypha* has formed a few dense steadily-extending clumps and may be worth encouraging specially. In parts close stands of *Combretum Zeyheri* and *C. apiculatum*

or of the *Berlinia globiflora* saplings themselves are providing a most useful effect. An unburned piece of open "mbuga," also protected by St. Clair-Thompson and representing a feeding-ground of the fly, has densified satisfactorily, *Dichrostachys* being mainly responsible (Pl. xv, fig. 2).

The fly-work carried out at the same time produced three times the number of flies per hour of progressive reconnaissance from the regularly-burned and undensified *Berlinia-Brachystegia* than from the unburned and patchily-burned areas. They were practically all males in each case owing to the absence of hunger. An organised pupa-search by Jackson with half a dozen skilled natives produced, in an hour, eleven times more live pupae, and eight times more live pupae and old shells combined, from the regularly-burned ground than from the country which had densified through not being burned at all. The corner of the latter which had not densified and the regularly-burned plot at its side showed approximately the same fly density as the regularly burned country. The "bad" corner, separately searched, showed also approximately the same high pupal density as the latter.

The difference in the number of flies was in spite of the fact that, there being no sort of a barrier between, there must be a strong and continuous infiltration of the flies into so narrow a piece of unburned ground, and the further fact that the dry-season conditions and advanced leaf-fall should have been making the thicker country relatively more attractive.

The presence of the corner which had failed to thicken up and the position as regards the tsetse within it, together with our results in Kikore, confirm the expectation that there will be pieces of country, whether they be mere patches or complete fly-belts, to which supplementary or quite different measures will have to be applied, no matter how successful or otherwise prevention of burning may be elsewhere; or which will require to be isolated from the areas not burned. A possible supplementary measure which may be referred to before leaving the subject of Itundwe is that of "assisted" densification of the wooding. St. Clair-Thompson's planting experiments here in the *Berlinia-Brachystegia*, unweeded purposely during four of the five years of their existence, show promise on the part of two species of *Rhus* (*R. lancea* and *R. glaucescens*) and of a useful tree, *Cassia siamea*, which succeeds where the canopy is poor and is likely to regenerate itself in leaf-litter. *Dodonaea viscosa* has grown well and produced close thicket, but despite copious seed production is not regenerating. *Leucaena glauca*, a good spreader, has done well in itself but is continually eaten back by elands. Two conifers, *Cupressus arizonica* and *Callitris calcarata*, have succeeded in Kikore, but would need to be laid down as definite plantations instead of merely being introduced here and there and allowed to spread of themselves.

This last is of course the thing aimed at and a bird- or mammal-dispersed plant would seem best. The *Indigofera* itself may prove excellent. Its range coincides with much of the local range of "Miombo"—both of *Berlinia-Brachystegia*-spp and of *Brachystegia microphylla*. With *Rhus glaucescens* under good rainfall, by itself or with *Abrus Schimperi* under somewhat drier conditions, it forms thicket under good canopy (of Miombo) where allowed to by fires or stock. As it is eaten by the latter, it would still be useful when the tsetses were finally out and, after its destruction by cattle, it would give way to grass without any expense to ourselves and without burning the humus. Unfortunately a small larva eats its seeds wholesale. It may be that the extirpation of a tsetse-fly will depend here on the biological control of an insect that eats Indigo seeds! An exotic plant might for long avoid enemies. *Tecoma stans* and Ceara rubber (*Manihot Glaziovii*) spread rapidly, and the former is tolerant of canopy. Guavas (*Psidium* spp.) might form thicket in Kikore as readily as in parts of Rhodesia.

The plots at Kikore have been very disappointing during five years as regards woody densification. They have, however, as stated already (p. 421, and Scott,

1934) given important indications as to the factors which the changed ground conditions are bringing into existence. They have, in addition, shown that under certain conditions (presumably of greater humidity than exists at Itundwe) the growth of the seedlings of the savannah species at least, including *Berlinia*, is inhibited by leaving the grass unburned. Thus of the numerous seedlings marked by Scott up to five years ago in a *Berlinia* plot practically none are now over seven inches high and most are but three or four.

This matters less in the plains communities at Kikore, for, as Nash (1933, p. 120) has described, the plains have shown themselves capable of extirpating their "fly" if aided by a deluge of rain. It is the *Berlinia* and *B. microphylla* communities on the scarp face and its foot that enable the tsetse to survive these periodic disasters and it is these we must concentrate on here. Fortunately there is a hopeful indication. In the *Berlinia* plot referred to, few low woody plants are happy, but a few definitely are; these are plants of dense thicket—*Thunbergia* and *Allophyllus africana*. It would seem from the whole result (a) that the plot is merely awaiting an appropriate "thicket" seed-supply in order to densify duly, (b) that under the local conditions with fires excluded, *Berlinia* will give place to a new plant community when the present generation of trees and saplings has passed. Further, there is at present no *Indigofera* in the plot; this illustrates the "hit or miss" limitations of very small plots—in which only, however, all individual plants can be listed and watched.

A two-mile strip has been demarcated in Kikore for a fuller experiment, and the Itundwe protected area has been extended up to fly barriers, present and projected; further, it is being recommended that the custom of not burning the grass, which prevailed in Singida before "fly" drove the cattle out, shall be continued now the cattle are not there to keep regeneration suppressed, and a really large area has been selected in the Western Province for a closely-watched experiment in not burning (Pl. xvii, figs. 3, 4). It is hoped thus to discover the extent to which this apparently promising, though not universally applicable, measure will be of use for *G. morsitans*.

4. Applicability of the Method to other Tsetses.

What will be the effect on *G. brevipalpis* and *G. pallidipes*? *G. brevipalpis* is associated with the ultimate stages in our vegetational succession, so not burning is more likely to assist it than otherwise. Pending fuller observation or special experiment we must be careful not to apply this measure in close proximity to areas in which it occurs. For an example of *Berlinia-Brachystegia-Uapaca* wooding densified to the point of supporting *G. brevipalpis* see Swynnerton, Bull. Ent. Res., 11, pt. 4, Pl. xii, fig. 2.

G. pallidipes is much more important, for besides being a more dangerous fly, its distribution overlaps more than half of the total distribution of *G. morsitans* and *G. swynnertoni* in Tanganyika. Our continued experiments will elucidate the question whether we shall be helping or hampering it. In the meantime it is to be noted that in Block 4A its numbers (originally small) have come down, by no means in the proportion of those of *G. swynnertoni*, but still decidedly; while in Itundwe the bush as modified by not burning the grass looks suited to *G. pallidipes*.

5. Practical Application if Successful.

As regards the suitability of densification of vegetation as a measure for defence, a tsetse-advance appears to depend for rapidity on the density of the flies behind; and omission to burn the grass in our *swynnertoni* experiments has, as here stated, reduced density rapidly. Naturally, however, this measure, if it should prove successful, could be employed as much for attack as for defence, or for defence and attack simultaneously. In the latter case the expenditure, which would be relatively small if the process were not too prolonged, would cover two objects. The unburned

strip might be a considerable number of miles wide to prevent possible passage by small numbers of flies, and its fire-breaks would move progressively forward. It would be replaced at a safe distance behind with as much burning as might be desired for the restoration of pasture, and the diminishing area of infestation ahead would also each year be burned to attract the flies into it. Or, with sufficient organisation, a whole fly-area might be dealt with at once. Even if a large proportion of the pasture went to dense thicket, additional counter-balancing advantages would have been gained from the annual deposition of humus which would not be burned off and from the lessening of run-off and erosion and the probable improvement of the waters; the area would be regarded as an Agricultural Reserve, and the introduction of settlers when the tsetse were entirely driven out would gradually but automatically re-provide grazing. The natural regeneration of useful timber trees, such as *Pterocarpus Bussei*, *Afrormosia angolensis* and *Azelia cuanzensis*, would also have been rendered possible.

It may be objected that with the whole country like tinder it will be impossible to exclude grass-fires either generally or continuously. Certainly there will be losses, in the first year especially, as there were in Shinyanga when we first controlled fire over a very great area; but the effort in each locality might be needed for a few years only, and our experience suggests that, while trouble may be expected initially and local set-backs continuously, good organisation on the Shinyanga lines, with the use of sufficient fire-breaks, will render the measure a general success—provided that the Government adopting it and the Administration of the district concerned with it are completely determined to carry it through.

If it *should* prove successful against the tsetse, even as a basal measure, it will be well worth determined support, for it is difficult to imagine anything that could be cheaper or, from all view-points, entomological, agricultural and silvicultural, sounder in principle. The vexed question of the game would be settled by it; for, to judge from Block 4A, there would be no need to take steps against the animals unless they were anywhere so abundant during the application of the measure as to keep the vegetation grazed down; and with the tsetse ousted, there would no longer from this point of view be any need for concentration of the natives in settlements to form parts of barriers that would ultimately cut up the fly-bush for the application of exterminative measures in the areas between: the advanced succession would be both a reclamation measure and a barrier in one.

It may be added that there have been many cases in which unburned areas have been entered by advances of tsetse, as now in Singida, but in each of these cases the grass was kept down by large numbers of cattle or was nearly non-existent in any case. The conditions of Blocks 10A and 4A were absent. It must be added also, however, that near the dry limits of a tsetse-fly's range the additional humidity and lowered temperature produced may assist the tsetse instead of destroying it.

6. Place of the Release of the Succession in the Experimental Scheme in Shinyanga.

As has been said, the same flies need different types of country and use them for different purposes, namely: thicket, for breeding in (*swynnertoni* and *pallidipes*) or as a refuge from fire and drought; open country, for finding food; and an intermediate type, to resort to when the extreme types provide intolerable conditions, whether of shade and humidity or drought. The enhancement of the natural growth of vegetation deprives the flies of the second and third types by turning these (for practical purposes) into the first.

An alternative mode of attack is to destroy or modify one of the types and leave the others. A highly useful experiment on these lines was conducted in Nigeria by Lloyd, Lester, Taylor and Thorneill (1933). Similar work has been done by ourselves on *G. swynnertoni*. Cutting out of the thickets only in certain experiments, of the thickets and scattered trees on the hard-pan only in another, in each case

combined with organised grass-burning, have proved definitely exterminative or expulsive for *G. swynnertoni* and *G. pallidipes*. Our present experiments (in Blocks 5B, 7C and elsewhere, see fig. 1) are directed to the trial of these and similar discriminative clearing experiments, based on our knowledge of the needs of the fly, under the ordinary native system of grass-burning.

In *Acacia* country with good grass (Block 6 and Chibe), the organised fires late in the season alone have done the work, flaming through the relatively small thickets and thinning out greatly even the large *Acacias*. This amounts to setting back the plant succession by the exact converse of the measure described in this paper. Direct effects on the flies and their pupae are also involved in this case.

There is still the further alternative of expulsion or modification of the food supply of the tsetse in carefully controlled experiments from which it is hoped to ascertain (a) what animals are and are not of vital interest to the fly, (b) whether anything short of the complete extermination or expulsion of animals will suffice to get rid of the latter, (c) whether such extermination (locally) is practicable by such means as are cheaply available to a government. Sites for these experiments have been selected and are under study, and a sanctuary with dams has been created across a clearing to which later to attract and drive the game. Details will be given in the Department's Annual Report.

The whole is an experiment with two aspects: (a) modification of food supply without modification of vegetation; (b) modification of vegetation without modification of food supply, unless the modification of the vegetation does not suffice. Thus:—

Blocks	Vegetation	Food	State of experiment
4A and 11 ...	Succession released	Untouched	4A well advanced, 11 this year
10A	Succession released	Increased by attraction	Well advanced and attraction provided
10C	Unchanged	Increased by attractions; tsetses to be trapped with the aid of the game	Attraction of water provided
9 and 10B ...	Unchanged	Modified in each case, first qualitatively, but differently, then quantitatively	Prolonged preliminary investigation in progress
10A later, if necessary	Succession released	Reduced	---
5B and 7C	Discriminative clearing	Untouched	5B well advanced
5B or 7C later, if necessary	Discriminative clearing	Reduced	---
10C later, if necessary	Discriminative clearing	Increased	Attraction provided
4B (control) ...	Unchanged	Unchanged	Long existing

Of these methods under trial the relapse of the succession, if successful, seems likely to be the cheapest as well as the most practicable in the absence of a large native population.

7. Summary.

1. From a block of country of four square miles, infested by *Glossina swynnertoni* and a few *G. pallidipes*, grass-fires have been excluded for three years in succession.

The tsetse-population has decreased in that time by nearly nine-tenths (from 9.4 to 1.0 flies per 1,000 yards of transect). In a block of two square miles it has decreased in two years without burning to the same average of one fly per thousand yards of transect from a high previous figure unmeasured. Two "barrier" strips following roads that previously were highly infested have also been unburned for three and four years respectively and have become similarly inhospitable to the flies.

2. In a control block of only $1\frac{1}{2}$ square miles, the grass has been burned in the ordinary native fashion annually during the same period. The average fly-catch per thousand yards of transect has increased since this was done from 4.2 to 13.1.

3. In each of these blocks game is about as plentiful as it was at the first. The 4-square-mile block shows a slight gain.

4. In the four experimental blocks and strips, but not in the controls, extensive thicket is growing up everywhere in the grass as a result of the exclusion of the fires. Thus the previous marked difference, both spatial and seasonal, between the respective densities of the different vegetational communities is commencing to disappear. Much grass-country remains but its average condition is one of long grass rising from a mulch, thick or thin and sometimes absent, of the previous year's grass that keeps the soil damp after rain—the more so since run-off is checked. Longer and denser grass is encroaching into the previously very open concentration sites of *G. swynnertoni*, which are also being invaded by thicket.

5. The contrasts between burned and unburned country are especially strong in the short wet season. At this time in burned country the flies have just gone through a period of intense desiccation, short hunger cycle and hardship, and the population is at its annual minimum. The ground, however, is very open and visibility of the other sex and of food animals and breeding-places is unimpeded. Conditions are suddenly made ideal by the advent of the rains. Humidity is added to temperature; the hunger cycle is lengthened; the openness and insolation of the ground now probably play a further beneficent part by preventing an excess of humidity. The flies are active, they breed freely, the shade conditions enable them to spread, and the density curve soars upward.

On the unburned ground the water-content of the soil is increased in the early rains, dampness is retained between showers, the temperature is lowered, evaporation is reduced, and light intensity in the grass becomes less (Scott, 1934). The activity and breeding of the flies is quite likely affected. The striking increase in the population that characterised unburned country in the early rains and short dry season is absent, and the density, having failed to rise at this time, continues low or falls further.

6. In two cases (*G. morsitans*, Nash 1933, at Kandaga; *G. swynnertoni* in Block 11 at Shinyanga) the second annual impetus to breeding, associated normally with the advent of the long dry season, duly produced its usual effect on the tsetse-populations of country that was in its first year of no burning. In the case of the block that has been unburned for three years this effect has been slight.

7. That the conditions, though deteriorating, are as yet not lethal through hunger, due to poor visibility or otherwise, is suggested by the fact that the very small fly populations referred to maintain a nearly stationary balance in at least the larger experimental block and do not show special hunger or other sign of distress. It is possible that most of the diminution hitherto has been caused merely by emigration to *better* conditions, for the blocks are not yet fully isolated. On the other hand, were the main effect on the breeding, distress would not be detected and the result might take place independently of any emigration. Reduced visibility of food animals may become operative later.

8. It is suggested by the results so far on the tsetse and by the present appearance of the country in these four experiments that with the further advance of the vegetational succession towards its natural climax the remaining fly population will probably

dwindle further and disappear—at least if the areas are isolated; the growing homogeneity in the density of the whole vegetation will reach a point at which it is unlikely to satisfy the daily and seasonal needs of an insect which for food, breeding and regulation of moisture and temperature, has a separate and vital use for each of the three densities furnished by thicket, savannah wooding and nearly open hard-pan and vlei.

9. The concentration sites of *G. swynnertoni* combine in a small space the types of vegetation the flies need, both the denser and the more open. They are important at all times but especially as refuges from unfavourable conditions elsewhere and as meeting-grounds of the sexes when the population is reduced. They are operative all the year round, and an effective change in these refuges alone in either the wet season or dry should be a shrewd blow at the fly. In experiments elsewhere in Shinyanga the clearing of the thickets at these places has quickly brought down the fly-population through its dry-season effect. In Blocks 4A and 10A the cessation of grass-burning is apparently already affecting these sites by hemming them in with areas presenting unfavourable conditions—probably mainly through excessive shade and over-humidity in the rains. The cessation of burning might even suffice if confined to these concentration sites and their neighbourhood.

10. As regards the probable effect of not burning the grass on other species of tsetse, it is considered that the method may prove useful against *G. morsitans* under moderately extensive vegetational conditions, though it may in this case take much longer and may not apply to large areas. *Berlinia-Brachystegia* wooding went to thicket in the writer's early experiments in a specially high rainfall area in Rhodesia, and (under lower rainfall) the exclusion of fire for five years at Itundwe (Central Province, Tanganyika) has produced strong densification in the *Berlinia*. In the Kikore plots (5 years protected) savannah type seedlings are being suppressed by the new conditions, but the flourishing state of the few shade-tolerating thicket plants suggests that all that is wanted is the introduction of a suitable seed-supply. This will be necessary in any case in all places without natural regeneration.

11. In an observation by Nash (Kandaga, Central Province) *G. morsitans* reacted initially in much the same way as *G. swynnertoni*, but the experiment was interrupted. In Itundwe *G. morsitans* and its pupae are much less numerous in the unburned *Berlinia* than in the burned.

12. The reaction of *G. pallidipes*, as distinguished from that of its habitat, is uncertain but so far has been promising under Shinyanga conditions; but the new conditions at Itundwe look as though they might favour this fly. *G. brevipalpis* is definitely likely to be favoured by the effect of not burning the grass.

13. The increase in humidity and lowering of the temperature produced by not burning the grass may be expected to be specially effective towards the wet side of a tsetse-fly's range. Towards the dry side it might even at first assist the fly.

14. Experiments to test the possibility of success against *morsitans* are being taken in hand, as are experiments on larger pieces of country infested by *swynnertoni* and *pallidipes*.

15. The control of grass-fires offers difficulties, but our experience over a wide area and many years shows that with determination and organisation it is quite possible, though an occasional minor set-back must be expected. The advantages of this measure from other points of view than that of tsetse extirpation, and the means of restoring the pasture, are referred to on p. 425.

8. Conclusion.

While it is believed that the vegetational results described are broadly indicative of what would happen in most *G. swynnertoni* country, in a great deal of *pallidipes*

country, and in at least some *morsitans* country, it is thought that over a much larger area and one without an outlet for escape, the effect on the tsetse may take longer to come about, especially if the tendency for the numbers to rise at the end of the long rains should apply to unburned areas. Also that there will be obstinate pieces of country even here to which supplementary measures will have to be applied. It is preferred, therefore, pending the final results of the original experiments and those of the larger experiments that are commencing this year, to regard the release of the vegetational succession by the prevention of grass-burning as likely to be useful as a *basic* measure. By this is meant one that, where it applies, will so strengthen the "environmental resistance" to the continued existence of the fly that the latter will succumb more readily to an exceptional season or an additional measure of our own. It is fairly certain as well that the application of the prohibition of grass-fires will have to be excluded from the quite considerable areas with which *G. brevipalpis* is in contact—if not *G. pallidipes* also—so that the search for supplementary and alternative measures must still be pushed on with. Despite this difficulty, the release of the succession may by itself bring about the cheap reclamation of a good deal of country. It is at any rate hopefully regarded, though it is realised from the indications at Kikore (p. 424) that the problem is not quite simple and that much work remains to be done.

9. Acknowledgments.

Our efforts in permanent fire-exclusion here described have been incidental to an annually carried out scheme for temporary fire-exclusion from a very large area for our "organised-burning" experiments. This work for some years has come under Mr. S. Napier-Bax, Senior Field Experiment Officer. I wish to pay a tribute to his very fine organisation and also to the way in which Mr. A. Lombard, under him, has carried out the details of the fire-exclusion measures. The Entomologists successively stationed at Shinyanga—Dr. C. H. N. Jackson, Mr. H. M. Lloyd and, for two years past, Mr. W. H. Potts—have, by means of their fly-rounds, carefully watched the effect of our measures on the flies and I am indebted to Mr. Potts (the originator of the fly-round method) for the fly-figures given in this paper. He is engaged now on climatic reaction experiments—on which subject Professor P. A. Buxton has given so excellent a lead. They are likely to help to explain the diminution of the flies and perhaps to improve our attack. Some of the work initiated by Mr. G. W. St. Clair-Thompson at Itundwe has proved of great use. Mr. D. D. Burt, Tsetse Botanist, has made an excellent and very detailed botanical survey and map of Block 10A. Mr. H. Harrison, during Mr. Burt's absence on leave, is extending this survey and map to Block 9 (the control area), earmarked as it is for a game experiment later. Mr. Harrison and Commander D. E. Blunt, to the latter of whom I am indebted for most of the photographs here included and (with Mr. N. H. Vicars-Harris) for extracting the graph, are in charge of different parts of the game work. Burt's prolonged investigation, in the Central Province, of the relation of dense thicket to *morsitans*, carried out with Harrison's assistance and still unpublished, has been very suggestive and relevant, and I should like also to refer here to the fine pioneer field-work of Drs. Jackson and Nash on the effects on the fly of varying evaporation—Jackson as regards its immediate effect, in the production or lessening of hunger, movement and use of feeding-grounds, Nash also as regards its subsequent effect on fly-density. More than anything up to the present these investigations have explained the habits, movements and fluctuations of the flies and will, with Potts' present experiments and the extension of some of the painstaking work done by Scott under Phillips, go far to account for the phenomenon described in this paper.

I am grateful to Sir Guy Marshall and Dr. S. A. Neave for their trouble in seeing this paper through the press.

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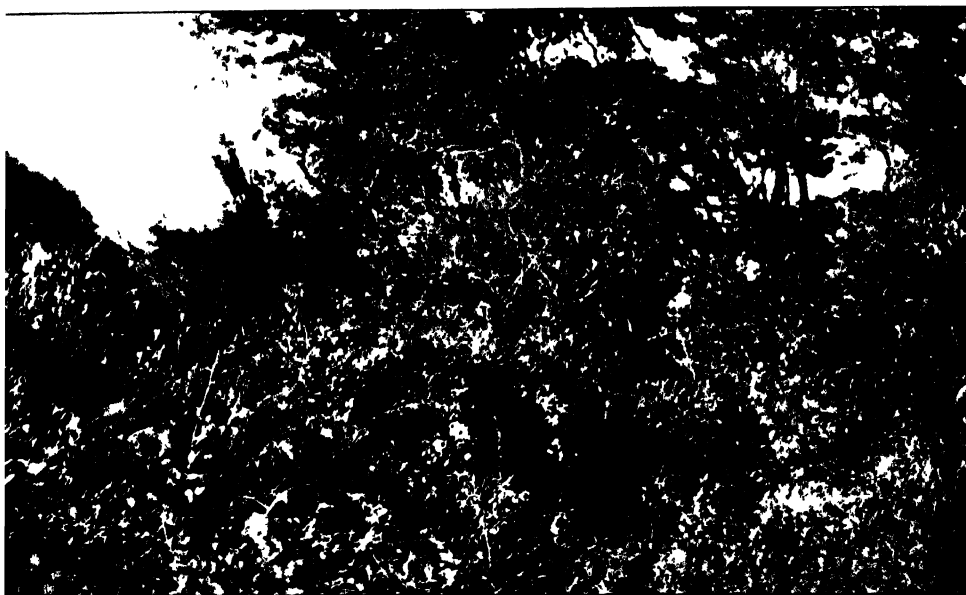


Fig. 1.

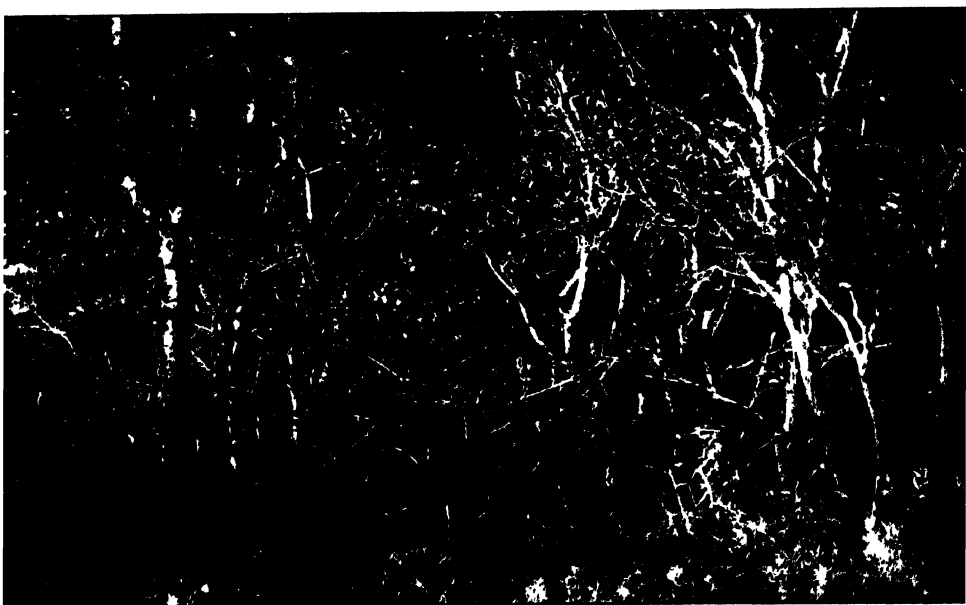


Fig. 2.

EXPLANATION OF PLATE XIV.

- Fig. 1.—Effect of exclusion of fire in the neighbourhood of rain-forest, Chipete, Southern Rhodesia. *Acacia natalitia*-long grass-bracken savannah invaded first by a tangle of shrubs and climbers—*Dioscorea schimperiana* and *Cluytia Swynnertonii* recognisable; secondly (on right), by tall *Albizzia* trees formerly only on the forest outskirts; thirdly, on right (not showing), the rain-forest, bird-carried seeds of which are already germinating everywhere in the thicket shade. Branches of the original *Acacia* trees, killed by the new conditions, show above the tangle.
- Fig. 2.—Effect of exclusion of fire from *Berlinia-Brachystegia* wooding under a good rainfall near Chirinda (Mount Selinda), Southern Rhodesia. A hat on a low tree-trunk near the left gives the scale. On the right, *Parinarium curatellaefolium*. This margin had been scorched some weeks prior to the taking of the photograph. The area before fires were excluded was as open between the trees as in Pl. xiii, fig. 1, of Bull. Ent. Res. **11**, pt. 4.

EXPLANATION OF PLATE XV.

Fig. 1.—In the edge of block 4A, Feb. 1931, before fires were excluded.

Fig. 2.—Effect of densification in a *G. morsitans* " mbuga " feeding-ground in a five-year exclusion of fire through upgrowth of *Dichrostachys glomerata*. At Itundwe, season of leaf-fall.



Fig. 1

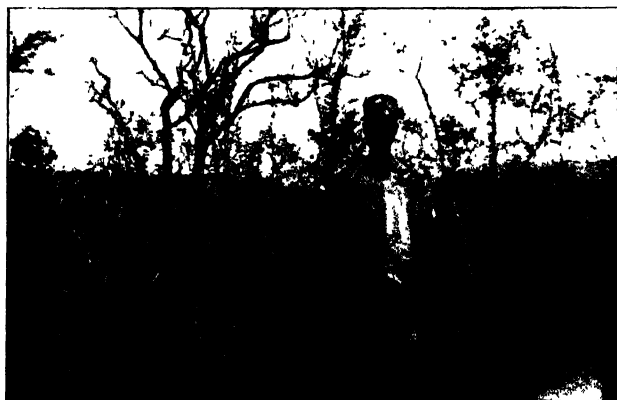


Fig. 2.



Fig. 1.

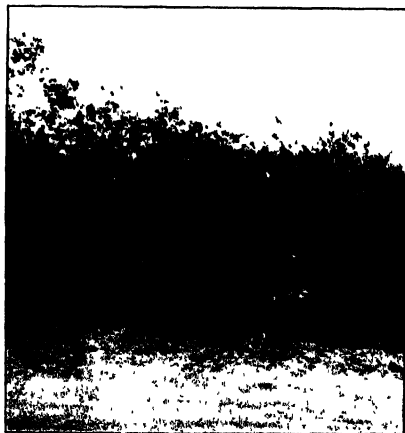


Fig 2.

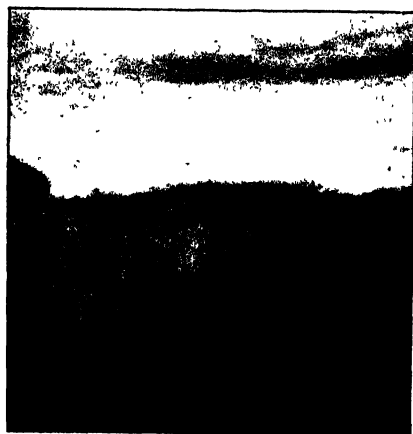


Fig. 3.



Fig 4.

EXPLANATION OF PLATE XVI.

- Fig. 1.—The same site as Plate xv, fig. 1, after three fires had been missed ; the tree behind the native's hat is that shown behind it in the above mentioned figure. Typical of the thicket growth—*Dolichandrone acuminata*, *Ormocarpum trichocarpum*. *Dichrostachys glomerata*, *Abrus schimperi*, some *Grewia*, etc , which is coming up brokenly all over the block.
- Fig. 2.— Exactly opposite Fig. 1 and merely across a road, the site shown at an earlier stage in the Annual Report, Tsetse Research, Tanganyika, of December 1930, Plate v, fig 7, opposite p. 17. In the Mantine Road " Thicket Barrier," which was burned last in June 1929 and has now missed four fires. Typical of this barrier generally.
- Fig. 3.—In an " mbuga " in block 4A ; three fires missed, much young thicket showing, much still concealed by the grass. Flies reduced to a tenth since grass-burning stopped.
- Fig. 4.—Young *Dichrostachys* in 4B burned back each year by the fires but ready to produce the effect shown in Fig. 3 and Pl. xvii, fig. 1, if fires were stopped.

EXPLANATION OF PLATE XVII.

- Fig. 1.—In block 10A, two fires missed. A young thicket of *Dichrostachys glomerata* at the back, a more backward thicket of *Ormocarpum trichocarpum* in the grass everywhere else. Typical of the condition over wide stretches of 10A.
- Fig. 2.—Successive annual mats or mulches of old, grey, dry grass where fire is excluded, the lowest already decomposing into the surface soil. The ground remains damp under these for days after a shower.
- Fig. 3.—Effect of densification in the *Berlinia* "home" of *G. morsitans* at Itundwe after five years exclusion of fire through upgrowth of *Indigofera* sp. Season of leaf-fall.
- Fig. 4.—Immediately beside photograph shown in fig. 3, but in the annually burned control. *Indigofera*, etc., present, but no upgrowth. At Itundwe.



Fig. 1

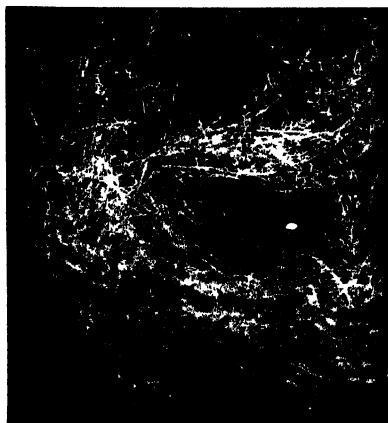


Fig. 2.



Fig 3



Fig. 4.

TSETSE-FLIES IN THE MASAI RESERVE, KENYA COLONY.

By E. ANEURIN LEWIS,
Veterinary Research Laboratory, Kabete.

(MAP.)

Our knowledge of the distribution of tsetse-flies affecting domestic stock in Kenya Colony is of a very general character. A good deal of the information requires confirmation; and much needs to be done to ascertain the extent and the nature of the permanent fly-infested areas, and the seasonal dispersion of the tsetses from their permanent haunts.

Maps prepared for the administration of some native tribes, and for military purposes during the war (1914–1918), show areas as fly-infested which, to-day, are not considered so, though occasional outbreaks of animal trypanosomiasis occur there. The region below Athi River station, including Kiu and Kima, is marked as a fly-area in a map prepared by the military authorities in 1921. It was considered unsafe for horses because of the existence of tsetse-flies and the danger of trypanosomiasis infection. There appear to be no records of tsetses from here, although occasional cases of trypanosomiasis among cattle have been reported within recent years.

Dry (1921) failed to locate tsetse-flies in Kericho where trypanosomiasis breaks out, among stock, at varying intervals. The existence of the disease, perhaps, and the risk of infection of army horses may account for the inclusion of Kericho in the fly-infested areas.

There are no records of tsetse-flies from the Nasiandet, a tributary of the Mara in the Masai Reserve, although MacClure in his sketch-map in 1908 marks it as infested along its course from the Mau to its junction with the Mara.

In the Masai Reserve tracts of country with good grazing are uninhabited. When questioned as to the reason for this the natives stated that a dreaded disease, such as East Coast fever, kills off their cattle.

Tsetse-flies are said to exist in still other parts—native reserves and alienated areas—because outbreaks of trypanosomiasis occur from time to time. It appears that areas once free from tsetse-flies have gradually become infested by flies from adjoining country; and there is reliable evidence that the advance of the fly is continuing.

The relation of tsetse-flies to animal trypanosomiasis has been studied when outbreaks of the disease in certain parts of the Colony have caused mortality, or have crippled the normal movements of stock. Such outbreaks have occurred where no tsetses have ever been known to exist. Upon investigation it has been found that some of these were due to stock having been taken through known fly-belts; others are still unsolved. Many cases of the disease, resulting in losses, have been reported on farms adjacent to known fly-belts. Entomological investigations have shown that these were due to seasonal migrations of the fly. In a few instances only has the extent of migrations, or the zone of dispersion, been investigated.

While engaged on a survey of the ticks in the Masai Reserve, I took advantage of the opportunity to gain some further information on the distribution of tsetse-flies. My observations cannot be considered as complete, for it was not possible to make a thoroughly exhaustive investigation. A certain amount of the information included in this account has been gleaned from unpublished reports in the archives of the

various departments, from a small number of publications, and records of tsetse caught and entered in the Entomological Register of the Department of Agriculture of this Colony.

Several important new facts, however, are brought to light which clearly point out the need of adopting measures to safeguard against loss of further valuable tracts of country in the Masai Reserve ; and to reclaim the fly-infested, rich pasture-lands in order to relieve congestion and to facilitate the administration of the Masai people.

As may be seen in the provisional map at the end of this report, the present-day Masai Reserve extends from about $34^{\circ}37'$ to $30^{\circ}15'$ E. Long. ; and from about $0^{\circ}34'$ to $3^{\circ}10'$ S. Lat. The reserve occupies an area of nearly 10,000,000 acres, of which, roughly, 3,000,000 are arid or semi-arid and can be utilised for cattle grazing only during short periods in a normal year. It is estimated that approximately 800,000 acres of pasture-land are rendered useless because of infestation by tsetse-flies, whilst additional areas amounting to nearly 300,000 acres are contaminated by the tick-borne disease, East Coast fever.

The Masai have inhabited the country comprising the present reserve ever since, and probably before, the year 1890. In 1904 the region between the Uaso Nyiro River and the Mara (Amala, Engabei) River was exchanged for an area of land (Northern Masai Reserve) in the Laikipia district. In 1911, those Masai who had moved to Laikipia returned to what was then termed the *extended* southern Masai Reserve, which was between the two rivers mentioned above. The natives informed me that the country to the west of Mara River, and extending to the Kavirondo Reserve, has always been in the hands of the Siria section of the Masai tribe.

Arising out of the arrangements to concentrate the Masai into suitable and convenient reserves, several tours of inspection were made prior to the final allotment of land. The suitability of the extended Southern Masai Reserve for the Masai cattle was contested by the natives, but the reasons given appeared to be inconsistent with the findings of the several investigators. In December 1908, MacClure, in an unpublished report, stated with regards to tsetse-fly in Osero, that he found the ravages of this insect confined to the country lying close to the German (Tanganyika) border. A sketch-map accompanying a report of a tour through the proposed extended Southern Masai Reserve by MacClure & Monckton in the same year shows the distribution of tsetse-flies. Additions were made by an Intelligence Officer in 1914 ; and the whole map was revised in 1919.

The sketch-map shows both banks of the Uaso Nyiro, from the Tanganyika border to a distance of about seven miles below the Narosura River, infested with tsetse-flies.

On the west bank of the Mara River is a fly-belt of about 3 miles wide and extending up the river for about 24 miles from the Tanganyika boundary ; on the east is a wide area from the territorial line, and along the river for about sixteen miles. Extensions of the eastern belt are shown along the border to where the Ol Keju Longayanett leaves Kenya Colony and continuing with the course of this river to within three miles east of the Kipaapaia Hills ; along the Naitorr Lera stream and a smaller stream running into it ; also along the Ol Keju Talek to where the Ol Arorok joins it. The presence of tsetse is shown on the Osinandei River ; and on both sides of the Nasiandet River which rises in the Mau and runs into the Mara a few miles west of Olmirani.

In 1909, the District Commissioner, Mr. A. C. Hollis, wrote a report on the proposed removal of the Masai from Laikipia to the Loita country. He said, " the whole area comprises about 2,300 square miles, one-half of which is useless during the greater part of the year, whilst in one-eighth a fly is found (a species of *Tabanus*) which, although it does not kill cattle like the tsetse, drives them frantic by its bite." In the same year Mr. Bagge, an Assistant District Commissioner, stated in a communication to the Secretary of the Administration Department, that the country

known as Osero (a Masai name for bush or forest) was infested with tsetse-fly, and all that part was looked upon as useless for cattle. Another administrative officer, Mr. E. D. Browne, who was stationed at Naivasha in 1911, said that the country along the Uaso Nyiro, below its junction with the Narosura River "is never inhabited by the Masai, apparently because of tsetse-fly; excepting a strip some 10 miles long and varying from a mile or so to some 8 to 10 miles, the land is stony to a degree and full of thorn-scrub. But where the Ngurumani are, is a belt of fertile country traversed by many streams which enter the Uaso Nyiro or lose themselves ere they reach that river." Mr. Hollis wrote in 1911 "the eastern side of the Amala is good sheep country but bad for cattle owing to the presence of a kind of gad-fly (*Tabanus* sp.). This district is called Osero. Between Osero and the Uaso Nyiro, i.e., on the Narosura River and in the Osobugo Oirobi and Osobugo-lo-Loita areas, you get excellent cattle country and plenty of water."

During a tour through Siria and Ol Orokuti undertaken in 1911 by the Director of Agriculture (Mr. A. C. MacDonald), accompanied by the Director of Public Works, a District Commissioner, and two prominent settlers, no signs of tsetse-fly were seen along the route traversed, and the cattle met with did not appear to be troubled by the ordinary biting-fly. On a previous visit the Director of Agriculture had observed a number of *Stomoxys*, and he stated that these flies were fairly common all over the Protectorate, but so far as was known they did not carry any cattle disease.

As a result of these apparently conflicting reports Mr. T. J. Anderson, Government Entomologist, was instructed in 1913 to tour parts of the Masai Reserve, and to investigate the whole situation from a tsetse-fly point of view. His report was not published until 1921.

Referring to the valley of the Uaso Nyiro (frequently called the Southern Uaso Nyiro to distinguish this river from the Eastern or Northern Uaso Nyiro in the Northern Frontier Province) or the Nguruman River, he writes, "The valley, ten miles from the German border to the Nguruman colony, where I crossed the Escarpment, is a fly-area. Two species were taken, *Glossina pallidipes* and *G. longipennis*." "In one case, after careful search, four specimens (*G. pallidipes*) were taken at least two miles from water." *G. pallidipes* was widely distributed. Contrary to expectation *G. longipennis* was found to be common on the moist swampy flats and on the bank of the river. This area, according to Anderson (1921), is unfitted for stock on account of both the fly and the nature of the pasturage. "The Western [?] bank of the river is in the original reserve and as the Eastern [?] side is flanked by an escarpment almost inaccessible for cattle, the Masai, according to their traditions, have never crossed this area. To get from the old Reserve to the extension they go further up the river where the escarpment tails off and where there is good pasturage and no fly. They also cross lower down near the border."

Anderson expressed the opinion that the presence of tsetse-fly in the valley of the Uaso Nyiro, therefore, could not be regarded as seriously affecting the removal of the Masai from Laikipia to the extended reserve.

(The question marks after Western and Eastern have been inserted because the escarpment is on the western side of the river. For "Western" should be substituted Eastern, and "Eastern" should be read as Western.)

A continuation of the tour through the country between the Uaso Nyiro and the Mara River revealed no tsetse-flies (*G. pallidipes* or *G. longipennis*) on the slopes of the Nguruman escarpment and for six or seven miles in a westerly direction from the top of the escarpment; that is, in the stretch of country between Lengutoto on the west and the escarpment on the east.

In Lengutoto, Morijo, throughout Sianna, and in the southern section of Osero, no tsetse-fly areas were located. At that time Anderson found no species of tsetse along the course of the Mara River; and perhaps because he was unable to examine

more than a small part of the Gori valley, his search for fly there was unsuccessful. Thousands of cattle and donkeys were seen at that period on the land bordering the river, which made it seem probable that the valley was free from tsetse-flies.

Later in 1913, Woosnam (1914) made a journey down the Mara in search of tsetse-flies. Previously, the District Commissioner, Mr. R. W. Hemsted, had actually caught flies, which he took to be *Glossina*, on the Enderrit River, a tributary of the Mara. Woosnam collected a small number of specimens on the Enderrit River only, although the Masai had told him that tsetse-flies existed on some of the small water-courses coming down from the Isuria escarpment, and running into the Mara. He was informed also that tsetse were to be found all down the Mara River from a few miles below the present Mara bridge to the Tanganyika border. From the data collected he concluded that the fly on the upper part of the river was confined to the west bank, and that it strayed only occasionally to the east bank.

Although the presence of two species of *Glossina* was suspected the only specimens collected by Woosnam were identified as *G. fusca*. Later this identification was corrected, by the authorities at the British Museum, to *G. fuscipleuris*.

In the report on the "Tsetse-fly in the Masai Reserve" (unpublished) written in April 1914, Mr. R. W. Hemsted stated that the only region where fly prevailed to such an extent as to render it unfit for cattle was that lying near the lower reaches of the Uaso Nyiro. It was inhabited by the Ngurumani, apparently a branch of the agricultural Masai, who possessed fairly large flocks of sheep and goats, but who, it was believed, never kept cattle. Fly was also known to exist generally in small isolated patches in the country drained by the Mara River below an altitude of about 4,700 feet;* it was fairly prevalent in the neighbourhood of the hills called L'ol Duruki, in the valleys of the Ol Keju Longayanett, the Ol Keju Talek, and again on the banks of the Mara River. According to this report, all these places have been inhabited for many years by Masai, and the mortality among their cattle from any fly-borne disease was very slight. The Ol Orokuti country was considered fairly free from fly, but the latter was found in one or two other places, notably in the valley of the Osinandei stream, and on the lower Mogor, Kaiyan, and Engare Rongai Rivers.

Apparently from information given to him, Swynnerton (1923) points out, and illustrates in a preliminary and provisional map, that where the Mara crosses the territorial boundary, there is, at the foot of the Isuria escarpment in Kenya, an area inhabited by *G. pallidipes*. *G. fusca* is shown far up the Mara River also. Dealing with the various species of *Glossina* in the Mwanza province, Tanganyika Territory, and south of the Tanganyika-Kenya border, he states that, "As Mr. T. J. Anderson informs me that there is no doubt as to the fact that the large tsetse found hitherto north of the Kenya border is *G. fusca*† only, and as there is equally no doubt that the specimens taken by myself and my native collectors as far north as Mara Bay are *brevipalpis*, it would seem that the Kenya-Tanganyika border may at this point constitute approximately the dividing line between these two flies." Writing of *G. pallidipes* in the Mwanza district and the adjacent areas in Kenya, Swynnerton remarks that further north of Ikisu "on the Kenya side of the border and also on ours, definite *pallidipes* areas exist, and this is the only fly of the *morsitans* group that is known to occur anywhere in Kenya." On his map, what is known as Osero is marked as "Tsetse according to the Masai."

From time to time, and particularly during military operations between 1914-1918, tsetse-flies have been collected, and fly-belts located in the Masai Reserve. Many of the records, however, are not in the departmental files.

An account of the types of country in the Masai Reserve has been given in a publication dealing with the distribution of ticks. In order that this report may be

*Woosnam records *G. fuscipleuris* at 5,200 feet, on the Enderrit.

†Actually *G. fuscipleuris*.

comprehensive in itself, a general description of the topography and the vegetation, so far as it is known, is included.

The Tsavo and Rombo Rivers, at an altitude of about 3,000 feet, form the southern boundary of the Masai Reserve. The riparian vegetation is thick and comprises tall, shady trees with many Acacias. Unfortunately no specimens have been collected for identification. In the south-east corner of the reserve and immediately north of the Tsavo, is a group of hills with Ngulia on the boundary rising to nearly 6,000 feet. The hills and the country as far as the Chyulu range are thickly covered with "Olongongwen" (*Acacia mellifera*?) and other thorn-trees. The belt of thorn covers a strip of about six miles wide along the bank of the Tsavo, and a much narrower strip on the courses of the Ol Olturesh and Kikalelwa. Open plains with volcanic rocks between the thorn-belt of the Kikalelwa and the western slopes of the Chyulu hills occupy an area about eight miles wide and over twenty miles long. To the west of the Kikalelwa there is a considerable amount of low thorn scrub. Here and there are seen extensive beds of lava, probably derived from the activities of the present inactive volcano of Kilimanjaro.

Crossing this country with a gradual rise to the mountain, the Kuku Plain is reached at an altitude of about 4,000 ft. The valley of Kikalelwa winds round numerous kops and through swampy grounds to the west of the plains and at the foot of Kilimanjaro. At Loitokitok the forest area, with its cedars, begins. Definite records of *Glossina* found in the extreme southern end of the reserve appear to be few. A map, apparently prepared during the war (1914-1918), shows that the valley of the Tsavo, as far as its junction with the Rombo, and the Rombo along its whole course are infested with tsetse-flies (*G. pallidipes* and *G. brevipalpis*). Along the Ol Olturesh and in parts of the Kikalelwa *G. pallidipes* only seems to occur. *G. longipennis* is also marked in the Tsavo valley.

The eastern boundary of the reserve, from near Makindu, runs parallel with the Kenya and Uganda railway. Frequently species of *Glossina* are attracted to the passing trains and carried considerable distances up-country, even as far as Naivasha, 184 miles from Makindu, where *G. longipennis* is commonly found.

In the neighbourhood of Simba station, but in the Masai reserve, the country differs from that around Kibwezi and Masongaleni, where in the early days of railway construction the surveyors experienced well-nigh insuperable difficulties in penetrating the thick thorn-bush. Near Simba the country is more open. The flat-topped Acacias occur in the river valleys and near seasonal swamps; the scanty-leaved and more stunted Acacias form comparatively small areas of open thorn-tree country. Towards Sultan Hamud and on the hills to the south-west evergreen coppices and thickets are more abundant, and behind Olmundus hill there are heavy timbered trees. Patches of dense "Olerai" acacias exist on both sides of the railway—on the alienated farms near Kima, as well as on the Masai side. The nature of the vegetation at Sultan Hamud, the thick clumps of bushes, appear to be well-suited to the habits of *G. brevipalpis*. Only two specimens of this species have been collected from Olmundus.

According to the Masai, tsetse-flies are present during and for some time after the long rains in the neighbourhood of Lorgasailik, a prominent hill (5,000 ft. high) north-east of Lake Magadi. Near a swamp at the foot of this hill, there is thick bush favourable, it would seem, to *G. brevipalpis*. Specimens of *G. pallidipes* and *G. brevipalpis* were collected at 3,850 feet.

In the south-west of the Rift Valley in Kenya is the tsetse-infested area of the Uaso Nyiro or Nguruman at about 3,000 feet. Anderson (1921) writes of this region "on the western side of the river, and running parallel to it, is a high escarpment, in parts precipitous. Between this escarpment* and the river is a low-lying tract of country, swampy, one to three miles wide and covered with dense bush and tall,

*The escarpment rises to 7,000 feet on the west.

coarse, rank grass. On the eastern side of the river the country is swampy and covered with coarse grass. . . . This area is a difficult one to travel through, as at one time the porters were cutting a path in dense bush, or at another wading almost to the neck in swamps. In the dry season this valley must present an entirely different appearance, as when the bush and grass dry they are burned off by the Wanderobo.*

From the escarpment, and below the Narosura River, two small streams—the Mugurr lo Kinei and the Ol Osho Siruai—flow into the Uaso Nyiro. Probably it is along these two streams that tsetse-fly spread from the valley of the Uaso Nyiro in the rainy seasons to the thorn bush between the top of the escarpment and Lengutoto.

The remainder of the reserve, to the west of the Uaso Nyiro, was toured during the months of November and December 1932, and in January 1933. Previous to this period I had discussed the question of a more thorough investigation into the distribution of tsetse-flies in this region with Mr. Swynnerton, Director of Tsetse Research, Tanganyika. It was hoped that it would be possible to carry out a survey on the Tanganyika side of the border as well as on the Kenya side.

I have already stated that beyond the records made by Woosnam no information was available concerning the species of *Glossina* which were said to inhabit the country under consideration. The reports of the presence and the distribution of tsetse flies differed; and in some cases appeared conflicting. With a view to clearing up the subject I included two tsetse-fly traps in my outfit. They were the Single Screen Awning trap and the Roller Screen (SR 1) trap described and illustrated by Swynnerton in "Some Traps for Tsetse-flies" published in this Bulletin in 1933.

The vast masses of hills known as Osobugo lo Loita (Loita Hills) and Osobugo Oirobi (Oirobi Hills) rise to an altitude of 8,000 feet. They are covered with thick forests, the cedar (*Juniperus procera*, Hochst.) being the dominant tree. The "Olerai" thorn trees (*Acacia benthami* and *A. hebecladoides*, Harms) are common at 6,400 ft.; the "fever-tree" *A. xanthophloea*, Bth., grows to a large size. *Carrisa edulis*, Vahl (Olmuriaki) and *Rhus villosa*, L.f. (Oloikilepoi) form fairly dense thickets between the larger trees and among the thorn-trees. *Tarchonanthus camphoratus*, L. (Ol-leleshwa) grows to tree-like dimensions up to 7,200 feet.

The thorn-trees are less robust and more stunted in the open glades towards Moriyo, and the country is of the savannah type. In Endasegera, a thick acacia woodland stretches for many miles to the Tanganyika border. Mbonget lies immediately east of the range of hills extending from Barkitabuk to the vicinity of the Ol Keju Longayanett, and which continues interruptedly to the Kipaapaia hills on the territorial boundary. The Rotuaik, as the range is termed, seem to be the present eastern limit of the tsetse-fly-infested area of Osero. Occasional cases of trypanosomiasis are said to occur among stock east of these hills. These are possibly caused by odd flies carried into the area.

The Narok-Barkitabuk-Pusimoru (or Kilimafeza) road runs along the western foot of the Rotuaik.

Osero (see map) is an area of approximately 700 square miles. It is considered to be completely infested with *Glossina swynnertoni* and *G. pallidipes*. From the Kilimafeza road to the Mara River, the level of Osero falls gradually from about 6,400 ft. to about 4,900 ft. The Sianna plains, the Angata le Malta and the Angata Bossi are about 6,000 ft. above sea-level.

Along the rivers Longayanett, Talek, Olare Lemun, Naitoor Lera, Ol Arorok and the numerous beds of smaller streams running into the larger river, the vegetation comprises *A. hebecladoides*, *A. mellifera*, *Acokanthera Schimperi*, *Oleo chrysophylla* and *Albizzia brachycalyx*. Away from the river-beds, thorn-trees are usually more

*A hunting tribe.

scattered and much smaller. Between the savannahs, and in regions of dense bush, patches of treeless pastures are numerous. On the slopes and at the foot of hills such as the Sianna, the Saaten, between the latter and the Lemaima Lumbwa hill in Tanganyika, dense forest and bush covers extensive areas. The dense vegetation is fringed by belts of thorn-trees, sometimes thick, sometimes open. Park-like glades are numerous. *Balanites tomentosa* (Ol-ngoswa), indicative of the dryness of the locality, and *Boscia caloneura* thrive in the open country and give the observer the impression of some of the beautiful parks in England.

In Ripoi and Robili to the west of Barkitabuk, in Saaten and Olare Lemun, I passed through patches of dense thorn, through the park-like areas, and rich glades. As I approached the bush, and on reaching the river-beds, numerous tsetse-flies were observed and collected. Near the water-holes, especially at one, Geigoro (5,700 ft.) which is frequently used as a camping ground by game-hunting parties, I captured dozens of *G. swynnertoni* and a few specimens of *G. pallidipes*. At another hunters' camp on the Talek River, there seemed to be a very heavy infestation of *G. swynnertoni*.

The plains of Angata le Malta and Angata Bossi, with "black-cotton" soil and a long growth of *Themeda triandra* grass, are broken into a meshwork pattern by numerous intersecting and narrow belts of thorn-brush. In these belts tsetse-flies were collected; but it is possible that many, if not all, had followed the car and lorry used for transport. In order to reach the Mara River it was necessary to cut out a path for the vehicles to pass through densely-growing *Acacia seyal* and another species known to the Masai as "Oljerai." Evergreen coppices bordered the more open country.

Arriving at a camp on the Mara and 26 miles below the present Mara bridge, I found a very luxuriant growth of riparian trees with a thick undergrowth of bush. The predominating trees were:—*Randia* sp., *Tecla nobilis* (Olgelai), *Gymnosporia senegalensis* (Ol-lamoronaii), *Haplocoelum foliosum* (Ol-tiasika) and *Hippocratea* nr. *loesneriana* (Ol-gisoshé). A sub-dominant growth consisted of *Flaucourtia Ramontchii* (Ol-morogi), *Rhus villosa*, *Gymnosporia* nr. *gracilipes*, *Capparis* nr. *tomentosa*, *Rhoicissus* sp. (Engelenyei), *Asparagus* sp. (Osinandei) and the epiphytic fig, *Ficus* sp. (Ol-reteti).

Acacia mellifera and *A. benthami* wooding form an open savannah on the margin of the thick riverine forest on both sides of the Mara. In trans-Mara, between the foot of the escarpment and the river, dense clumps of thickets in otherwise flat, open, grass plains are responsible for the park-like appearance mentioned by Woosnam. *Combretum* sp., *Cissus erythrochlora* (Ol-orondo), *Acacia pinnata* (Ol-girigiri), and *Capparis* sp., intertwine to form impenetrable clumps of bush.

An excellent bird's-eye view of the trans-Mara is obtained from the top of the Isuria escarpment. Below the Moyan, a tributary of the Mara, a narrow belt of thorn gradually merges into a large area of dense forest. A few miles south of this there extends across the country to the escarpment a narrow belt of the riverine forest of the Mara; it indicates the course of the Safaringo (Separingo or Ol Keju Lamongi) River. Tsetse-flies do not appear to have spread so far north as this river. On the east of the Mara the little Tusiek stream marks the northern limit of the fly zone, whereas the dense wooding of the Upper Enderrit represents the northern limit on the west of the Mara. Between the Safaringo and the Upper Enderrit, there are patches of open country broken by tongues of thorn-trees extending from the Isuria escarpment. Thickly growing, young Acacias show that the locality was fairly recently occupied, for here and there are definite indications of Masai bomas or manyattas. Thorn-trees are abundant along the Lower Enderrit and near Ol Doinyo Burgoi. In swampy ground near a salt-lick (referred to by Woosnam) a species of the *Phoenix* palms grows abundantly. The altitude south of Ol Doinyo Burgoi is about 4,500 to 4,900 ft. The Engarare River is more thickly wooded than the surrounding

savannah; but along the river and in the adjoining country *G. swynnertoni* is numerous.

On the Siria plateau (or hill) similar clumps of thickets to those in trans-Mara cover a large tract of land. The grazing appears to be excellent. It was not surprising to find the country free of tsetses at an altitude of just over 6,000 ft. The Masai stated that the tsetse-flies were confined to the region around Erok, and in the thorn-country extending to the Mogor River as far as Lolgorien. In Ol Orokuti the grazing is even more luxuriant than on the Siria hills, but the western and southern portions are uninhabited, mainly because of its infestation by *G. pallidipes*. A strip of thick forest crossed by the road from Mara bridge to the gold-mines at Lolgorien seems to be a continuation of the Chepalungu forest. On the eastern margin of the forest, I captured a single specimen of *G. fuscipleuris* at 5,900 ft.

The Masai are a nomadic pastoral people and readily move their homes and stock when in need of water and grazing. During the rainy seasons surface water and green grass is available in the normally arid regions; and the people and their cattle, sheep and goats, are widely scattered over the reserve. The Nyiri desert, parts of the Athi and the Loita plains, many of the smaller plains and areas in the Rift Valley soon lose the surface water and the grazing is soon used up. In the drier seasons, the tribes concentrate in the richer areas of the reserve. Congestion becomes acute, and many are compelled to seek pasturage for their stock near and in districts which they know to be infested with tsetse-flies or some other pest. Rather than lose all stock by starvation they venture into these districts with the hope, apparently, that at least a nucleus for future increase of stock may be saved. Long and bitter experience has taught these people the dangerous haunts of the tsetses. They seem to be familiar with the permanent belts of fly, and the general extent of their spread during and after the rains. When possible, they avoid infested zones until the flies recede to their limited permanent habitations.

In the south, the Kaputei and the Sighirari sections utilise the open grassland west of the Chyulu Hills. Kulale, the headman at Engoitokitok, told me that the Masai cattle are taken to these grazing grounds only when they know that the tsetse-flies have returned to the shelter of the bush near the rivers. He believed that tsetses lived in the trees and remained there until cattle came to drink, when the flies attacked them and sucked up the blood. When the rains were on, cattle were not so regularly taken to the more permanent watering-places, so that the tsetse had to fly some distance for food. He believed that tsetses did not like the strong rays of the sun, and therefore usually attacked stock in the mornings or evenings. "When the rains are on," he said, "we avoid these pastures because we know the habits of the fly."

Near Sultan Hamud there is excellent grazing. In spite of this, and of the available water in springs on the slopes of Olmundus, the area is severely left unoccupied. I carried out a careful search for *Rhipicephalus appendiculatus*, the vector of East Coast fever, believing that the Masai were confusing the existence of that disease with trypanosomiasis. The tick was not found. Nor could I find any tsetse-flies, although the numerous coppices indicated that the statements of the natives regarding the presence of tsetses might be correct.

Native stock are grazed a few miles away, near Emali, but they firmly refused to be persuaded that their cattle would not contract trypanosomiasis on Olmundus. I arranged with the District Commissioner, Mr. Storrs Fox, to make a further investigation later in the year; he was of the opinion that what I had been told was perfectly correct, and two months later forwarded me two specimens of *G. brevipalpis* caught on the west of Olmundus. There is a stretch of forest in the neighbourhood, and oxen are employed in the transport of timber to the station. A thorough survey of this locality might serve to establish the presence of a fly-belt, and a possible cause of outbreaks of the disease on alienated farms in the vicinity.

A somewhat similar case is met with at Lorgasailik in the Rift Valley, and north-east of Lake Magadi. In the dry seasons cattle are allowed to graze freely near the hill, but in the rainy periods the place is avoided, because the tsetse-flies spread over a comparatively large area.

In the Uaso Nyiro valley, the Masai tribal section which resides in a small area near the border are more amenable to manual labour than the purely pastoral sections. According to Sandford (1919) the Ngurumani form a survival of the old agricultural Masai, but they have discontinued agriculture, and now live in the same manner as the pastoralists. Apparently, these people have always kept sheep and goats, but very few cattle. Anderson notes that in order to go from the east of the escarpment to the west the Masai go further up the river where the escarpment tails off and where there is good pasture and no fly. They also cross lower down near the border. It would be of interest to find out whether or not the sheep and goats are infected with trypanosomes.

Referring to the suggested removal of the Masai from Laikipia to the area lying between the Mara River and the Uaso Nyiro, in 1908, Sandford states that this area, like Laikipia, had formerly been occupied by various sections of the tribe—the Loita, the L'Otayok and the Damat, who had, for the most part, disappeared from the area. A small portion of the Purko section also appears to have resided in the district.

In the course of my journeys through Osero I observed many circular patches of young thorn-trees. My Masai guide informed me that the trees had grown on the sites of Masai bomas when the area was occupied many years ago. I asked him whether there were any reports among his people on the presence of tsetse-flies. He replied, there were flies, but not over the whole area, and that infested areas were avoided. Not many cattle died because of fly. There is evidence (Sandford 1919) that a large number of Masai, including Purko, moved into the trans-Mara country in September 1913, after Woosnam's discovery of *G. fuscipleuris* and his suspicion of the existence of another species. The inhabitants gradually retreated from the advancing flies; they lost many cattle, and now the area is completely uninhabited.

Cattle from the Siria Hills are sometimes taken down the escarpment to the salt-lick near Ol Doinyo Burgoi. Siria has been in the hands of the Masai for a considerable number of years. Apparently owing to East Coast fever, it is not so congested as other parts of the reserve. Smallpox and rinderpest accounted for the evacuation of sections of Ol Orokuti; and now, it seems, the presence of tsetse-flies renders large areas useless to the people and their stock. The fly-infested areas include the neighbourhood of Erok, the southern portion of the country between the escarpment and the Tanganyika border to the Osinande River. The hostile relationship of the Watende and the Masai accounts for some of the unoccupied areas. Cattle raids are said to be not infrequent. Olingendera, the Siria headman, told me that the extensive thorn savannah between Erok and Lolgorien is seasonally infested with tsetse-flies and that cattle are then restricted to the hills.

A number of herds are found around Lolgorien; they water in the Mogor, but are not usually allowed lower down the river than a salt-lick about six to eight miles above the ford leading to South Kavirondo and to Kisi.

In a memorandum on the conditions in the whole trans-Mara (including Siria) country submitted to the Land Commission in October 1932, a prominent settler states "The rest of Siria, approximately one-third, consisting of the Moghor (Mogor) valley, the southern parts along the Watende border and the Mara River (Orbulegel to Suria) are becoming less and less utilised. This is entirely due to tsetse-fly which seems to be generally present in the area. I have made the remark that fly is slowly spreading. Two years ago, for example, there used to be quite a number of villages on the lower parts of the Engare Engituak, which localities, these days, are carefully avoided by the Siria, after many cases of cattle dying from tsetse had occurred—a

fact which I think is also recognised and proved by the Veterinary Officer. Amongst other people, I know one man (Ole Kararam) who has lost, I should think, 25 per cent. of his cattle during the last two years, and who now, having lived for nearly ten years on the Engare Engituak, has been forced back from his old grounds to the Siria Hills by fly." Another case mentioned in this memorandum refers to villages which have been abandoned, and the people compelled to move to the hills to avoid the tsetse-flies.

The Masai custom of avoiding infested areas, the reluctance of the people to kill a dying beast, and their attitude to an examination of the stock, are largely responsible for the lack of information on the incidence of trypanosomiasis.

I was able to persuade some of the natives to allow me to slaughter and take blood-smears from a calf far advanced in disease. A few sick sheep were also slaughtered in the presence of a veterinary officer. The smears from the calf, and from a few adult cattle, revealed *Theileria parva* and *Anaplasma*. No trypanosomes were seen.

Among a flock of sheep grazing just within the fly-zone near the Barkitabuk-Kilimafeza road, a large number showed symptoms of a sickness called "Ol-tigana" of sheep. "Ol-tigana" is usually accepted as the term for East Coast fever of cattle; but as the Masai persisted in stating that "Ol-tigana" of cattle also occurred throughout Osero, I thought that this disease of sheep might turn out to be a tick-borne disease—perhaps Nairobi sheep disease.

One sheep was thoroughly examined, and killed. Blood, gland, and spleen smears were made, and tissues were taken to the laboratory for further examination. The symptoms were: oedema under the jaw, and a staring coat with loose hair which readily came off on clutching it; there was emaciation and general weakness, but no diarrhoea. The blood smears from this and two other sheep showed trypanosomes, which unfortunately were not identified. No evidence of the existence of Nairobi sheep disease could be obtained. It seems justifiable, therefore, to consider "Ol-tigana" of sheep in this district as being trypanosomiasis. It is hoped that further material will be collected for the study of trypanosomes in this area, and to investigate the possibility of infection in domestic stock, which sometimes enter the fly-zone.

Blood-smears and tissues were collected from a variety of game; but no trypanosomes were seen in any of them.

I know of no area, outside the game reserves, where the wild fauna is so abundant as in the *swynnertoni-pallidipes* area of Osero and the Mara valley, which are frequently visited by game-hunting parties from abroad, and provide a useful source of revenue.

In the fly-zone of Osero, trans-Mara and parts of Siria, the most abundant species of game were:—Thompson's gazelle (*Gazella thompsoni*), zebra (*Equus burchelli granti*), wildebeest (*Gorgon taurinus albojubatus*), kongoni or hartebeest (*Bubalis cokei kongoni*), Grant's gazelle (*Gazella granti*), eland (*Taurotragus oryx pattersonianus*), impalla (*Aepyceros melampus rendilis*), topi (*Damaliscus korrigum jimela*), roan (*Hippotragus equinus langheldi*), and the small duiker (*Cephalophus natalensis*).

Large schools of baboons (*Papio cynocephalus*) and a variety of other monkeys inhabit the wooded regions of Barkitabuk and Saaten, and along the Talek and the Mara rivers. The warthog (*Phacochoerus aethiopicus*) is ubiquitous, and a small mongoose was numerous near Saaten.

Near Sianna in the river-bush, and along the Mara, waterbuck (*Kobus defassa*), and buffalo (*Syncerus caffer*) are numerous. Rhinoceros is not uncommon, and hippopotamus is present in fair numbers. At Mara bridge, I saw fresh spoor of many elephant. These are said to come, during the rains, from the Mau forest, through Chepalungu forest and then down to the Mara and across the Mogor and thus to Tanganyika. Lion, cheetah and jackals are frequently met in the open country.

Thus in the absence of domestic stock, there would appear to be no scarcity of food for tsetse-flies in this region of the Masai Reserve.

In this report I do not propose to enter into the controversy concerning the influence of game on the species of *Glossina* inhabiting Osero and Siria. Swynnerton (1923) remarks of *G. swynnertoni*, which is also found in these areas, that it resembles *G. morsitans* in its savage attachment to man in the relative absence of game. He further remarks "I have seen no tsetse that so readily attacks man with cattle present, and no fly the females of which travel so freely and far on man. Both traits were undoubtedly due largely to the fact that in places in which they were specially prominent man had successfully replaced game as the fly's chief animal food."

G. swynnertoni readily attacked the personnel of my outfit where game was abundant and cattle absent. The Masai name for a tsetse-fly is Endorobo (or N'darobo, En'darobo, Ndorobo). Trypanosomiasis is also known by this, or one of the bracketed terms. At least two types are recognised by the natives. *G. pallidipes* (and *G. swynnertoni*) is known as Endorobo naibor—the light tsetse-fly. Specimens of *G. palpalis* on the Mogor confused them. *G. fuscipleuris* is called Endorobo narok—the dark-coloured or black tsetse. Probably *G. brevipalpis*, also, would be indistinguishable, to them, from *G. fuscipleuris*.

Hitherto, six species of *Glossina* have been recorded from Kenya Colony. Although various references have been made to the occurrence of *G. fusca* in the Colony, the specimens so labelled in the collection of the Department of Agriculture are all *G. fuscipleuris*. Also the *G. fusca* reported upon by myself (1933) are *G. fuscipleuris*. Newstead and others (1924) note that *G. fuscipleuris* from the River Amala (Mara) in the southern Masai Reserve have been reported as *G. fusca*. Still earlier references to *G. fusca* are now known to be errors in identification. Austen (1911) writes "*Glossina brevipalpis*, to which the name *G. fusca* has hitherto been applied in error, is the common large Tsetse-fly in many parts of south-central and East Africa. . . ." *G. fusca*, Walker, has not yet been collected in Kenya Colony.

The species of *Glossina* now known to occur in the Colony are:—*G. longipennis*, *G. brevipalpis*, *G. fuscipleuris*, *G. palpalis* (and its eastern variety *fuscipes*), *G. austeni*, *G. pallidipes* and *G. swynnertoni*. Of these, six are to be found in the Masai Reserve.

***Glossina brevipalpis*, Newst.**

This fly appears to be numerous along the banks of the River Tsavo in Masai-land. On a map compiled from data derived from various sources, and printed in Nairobi in October 1915, the distribution of this species along the Tsavo is shown. It inhabits a similar type of country to *G. pallidipes* in this district. Further south, towards the Zawani swamp in Teita and also near Tsavo station, *G. longipennis* exists along with *G. brevipalpis* just outside the riverine belt of bush, but in more or less dry thorn scrub. *G. brevipalpis* seems not to have invaded the country drained by the Ol Olturesh River.

In 1913, Dr. Small reported on an investigation into an alleged outbreak of plague amongst the Loitokitok Masai. In attempting to obtain information from a trusted Arab who had lived for many years on the Ol Olturesh, he was told by the Arab and some Masai—one of whom knew the scientific names for "*fusca*" (*brevipalpis*) and *pallidipes*, that "*fusca*" was common on all the water-courses in Loitokitok, and that *G. pallidipes* was absent. Dr. Small obtained specimens of *G. brevipalpis* from the locality.

It should be explained, however, that Loitokitok, as it is to-day, is an area at the foot of Kilimanjaro, and does not seem to include the valleys of the Kikalelwa, Ol Olturesh and the Rombo streams. From Kilimanjaro through Engoitokitok and to Rombo and Useri, I found no tsetses.

Two specimens of *G. brevipalpis* were collected on the western slopes of Olmundus, Sultan Hamud, and four specimens from Lorgasailik were sent to me by Mr. Storrs Fox. A small consignment from the latter place also contained two males of *G. pallidipes*. No *brevipalpis* were obtained from the Mogor River region, nor from Ol Orokuti; it would not be surprising, however, to find that the species did exist there.

***Glossina fuscipleuris*, Austen.**

Woosnam found this fly on the Enderrit, a tributary of the Mara (Amala or Engebai) river; and at an altitude of 5,200 ft. My Masai guide and scouts showed me two streams—an upper Enderrit and a lower Enderrit. I gathered from the old men on the Isuria escarpment that Woosnam obtained his specimens on the Upper Enderrit where the vegetation is very much more dense than on the lower stream. "Practically nothing is known of the nature of the haunts of *G. fuscipleuris* or of its bionomics. It is recorded as occurring up to 5,000 ft. above sea-level; and Gerard (1920) states that he found it by little streams which were bordered by luxuriant vegetation; that the flight was heavy and the flies extremely voracious" (Newstead 1924).

I collected many specimens of the fly in the thick vegetation on the Mara River, usually in the backwaters and short gullies opening into the river. The atmosphere was humid, and the well-worn paths of game (buffalo, rhinoceros and lion) indicated that these places were utilised by numbers of animals coming to the river to drink.

In the dense vegetation along the Upper Enderrit, and at 5,300 ft., three specimens were caught. On the east bank of the Mara—still in thick bush—six individuals were caught on a game path near the junction of the Naitorr Lera and the Mara. Near a salt-lick (4,900 ft.) at Ol Doinyo Burgoi, there is a permanent swamp with an abundance of palms of the genus *Phoenix*. While resting in the shade of a palm, at 2 p.m., a single *G. fuscipleuris* attacked me within a few seconds of my arrival. This individual, a male, pierced the skin immediately, unlike the majority of *G. swynnertoni*, which rested a little before proceeding to bite and feed. Another male attacked one of my boys under the arm. At Erok (5,900 ft.) two males and a female darted out of the thick bush near the Osinandei stream to my fly-boys at 11.30 a.m. At the Lolgorien camp, situated near the Mara and not far from another salt-lick, my personal boy caught a male which had bitten him at 7 p.m. He had no doubt disturbed this fly in clearing the brush for a fire; it had insinuated itself up his khaki shorts and had bitten him high up on the leg. As we passed through a strip of forest, at an altitude of 5,900 ft. or more, on the descent from the Siria Hills to Lolgorien I captured a female *fuscipleuris* on my car. At the ford which crosses the Mogor, I saw many flies of this species and a large number of *G. palpalis*. A few of the former, and two of the latter, were collected for identification. The tributaries of the Mara, especially that known as the Shiatier, seem to be infested with *G. fuscipleuris* and *G. palpalis*. *G. pallidipes* also, according to the Masai, would appear to be fairly widespread in the south Siria. The Masai state that *G. fuscipleuris* attacks cattle very readily, and they maintained that it transmitted disease to their stock.

***Glossina longipennis*, Corti.**

From the data which I have been able to collect, and from the evidence in previous unpublished records, this species of tsetse is by no means abundant in the south-east of the Masai reserve. On many occasions, specimens have been collected on trains, and there is no doubt that many have been conveyed for long distances beyond their usual haunts in this manner. To the east of the Chyulu Hills and at Simba station the fly has frequently been collected. However, the home of *G. longipennis* here is actually outside the Masai reserve; and its nearest haunts are in

the vicinity of Makindu, Kibwezi, Masongaleni, and in the Tsavo areas. Reference has already been made to Anderson's remarks on *G. longipennis* in the valley of the Uaso Nyiro River where "Contrary to expectation" he found "this species to be common on the moist, swampy flats and on the bank of the river. . . . However, despite the moist atmosphere it was very active in a region where one would naturally have expected *brevipalpis*. This species [*G. longipennis*] was also found to have a wide distribution."

***Glossina pallidipes*, Austen.**

There is no doubt whatsoever that this is the most widely spread species of tsetse-fly in Kenya Colony. It is found in the coastal area with *G. longipennis* and *G. brevipalpis* in Witu and Kilifi, where *G. austeni* is also present; it commonly occurs in the dense bush along the littoral to Mombasa, in the Shimba Hills (Digo), and as far south as the Tanganyika border. Both *G. pallidipes* and *G. brevipalpis* are present in large tracts of Teita and Ukamba, and along the Tana River to the Makuyu district. *G. pallidipes* occurs with *G. longipennis* on the route taken by the Kenya and Uganda Railway as far as Makindu and Kibwezi, from near which places I have received many specimens of *G. brevipalpis* also. In the Suk (West Suk and along the Malmati River, in Masol and Weiwei) and the Turkhana districts of the Northern Frontier province, and in the valley of the Kerio, *G. pallidipes* is common and seasonally ranges over wide areas of the country. The northern Uaso Nyiro, the Isiolo district (including Barceloi), Kinya Wells, and at least as far as Marsabit are inhabited by *G. pallidipes*. The species is found, in some of these localities, in the same type of country as *G. longipennis*. In the Kavirondo Reserve, particularly Central and South Kavirondo, large tracts of excellent land have been evacuated because of infestation by this common vector of animal trypanosomiasis. In South Kavirondo on the shores of Lake Victoria, and in the valleys of the Yala, Kuja and Gori, *G. palpalis* predominates, whereas *G. pallidipes* occurs in the Lambwe valley, and on the Gori and Mogor Rivers. Several small belts of *pallidipes* have been located in the Kamasia Reserve, and more are suspected near Lakes Hannington and Baringo, and on the Guscha Lugeri, Ol Arabel, Ol Mukutan and the Amaya Rivers.

In the Masai Reserve, the species under consideration is more widely distributed than has hitherto been realised. On the Ol Olturesh and along the Tsavo it is said to be very prevalent. Its seasonal dispersion over the adjoining country deprives the natives of good pastures. It renders useless, for some periods, the water supplies and grazing in the Nguruman valley and around Lorgasailik; and it appears to be the cause of the unsuitability for cattle of an area of land east of Lengutoto. In the Osero country the species is widely spread. I collected very large numbers of *G. swynnertoni* where *G. pallidipes* appeared to be less abundant. Probably the paucity of the latter was due to its habit of comparative inactivity during the day and its relative evasion of man in the presence of game. Specimens of *G. pallidipes* were taken about six miles south of Barkitabuk (6,100 ft.), at Sianna, in Saaten, on the Longayanett River and between it and the Tanganyika border. Further specimens were caught, with *G. swynnertoni*, on the east and west banks of the Mara River, on the Olare Lemun and the Ol Keju Talek. It was surprising that no *G. brevipalpis* were found, as the clumps of thickets seemed to be very suitable habitats. The altitudes at which *G. pallidipes* was collected ranged from about 4,700 ft. to 6,100 ft.

The nature of my tour precluded any attempts at a reasonably prolonged trial for the tsetse-fly traps. At Sianna, eleven *G. pallidipes* and four *G. swynnertoni* entered the Simple Screen trap; and at the foot of the Saaten hill (Saaten Point) one *G. pallidipes* was captured in the same trap. Numerous tsetses were attracted to the hessian screen. As many as 20 specimens were caught by fly-nets and off the screen within three-quarters of an hour. These were mainly *G. swynnertoni*. The fans and the roller of the S.R.1 trap were damaged in transit, and as it was impossible to repair them, the experiment was abandoned.

A few specimens of *G. pallidipes* were taken from the dense-growing thorn-bush on the Engarare River (which is the same as the R. Mirari on MacClure's sketch-map) and among the scattered thorn-trees on the Lower Enderrit at about 4,900 ft.

The Masai informed me that *Endorobo naibor* (probably *G. pallidipes* or *G. palpalis*) is abundant on the Mogor River, and that it spreads over the country from Lolgorien to Erok, and also into Ol Orokuti. Unfortunately I was not able to collect a sufficiently large batch of flies to verify these statements.

***Glossina palpalis*, R. D.**

Two males of this species were caught at the Mogor Ford at an altitude of nearly 6,000 ft. At this point many more small tsetses were observed flying up and down the river. It is probable that these comprise *G. pallidipes* as well as *G. palpalis*. *G. fuscipleuris*, also, was very active.

In the various records available to me, I find that *G. palpalis* has not been reported to inhabit the Gori and its tributaries in the Masai Reserve. There appears to be some confusion in the nomenclature of many rivers. The Gori in some sketches and maps does not seem to have its source in the Mau; it is shown only as far as Long. 34°50', Lat. 1°15'; in others the river is shown as rising in the Mau Hills, running a southerly course until it reaches the longitude and latitude given above, and then going westward to join the Kuja River before entering Lake Victoria. The Mogor (or Moghor) is here accepted as that river running into the Gori from the Mau and joining the Osinandei to form the Gori.

Cherret & Pugh (1911) state that *G. palpalis* exists for a distance of 30 or 40 miles up the Rivers Kuja and Gori. Apparently this distance does not include the Masai Reserve, and it seems that the fly has gradually migrated along the Gori and up the Mogor. Other tributaries, such as the Shiater, would provide means of spreading.

I did not have time to visit the reported infested localities of the Rongai and Kayan streams which join to form the Oyani, which, in turn, flows into the Kuja. The information collected by Mr. Hemsted (see Map) is interesting, and it would be of further value to survey the localities and identify the species of tsetses with which they are infested.

***Glossina swynnertoni*, Austen.**

Previous to my tour through the Masai reserve, *G. pallidipes* (and according to Newstead's scheme of grouping, *G. austeni*) was the only fly of the *morsitans* group known to occur in Kenya.

G. swynnertoni, also of the *morsitans* group, is now known to be abundant and widely distributed in Osero. The eastern limit of the infested area, where *G. pallidipes* is also found, may be taken as the road to Kilimafeza, Tanganyika, from about six miles south of Barkitabuk to the Tanganyika border. The range of hills immediately to the east of the road appear to form a barrier to further extensions to the east. The efficiency of the barrier is weakened by gaps through which the Ol Keju Longayanett and smaller streams flow from Ildungishu, Mbonget and the Loita Hills. The road which crosses the Longayanett and passes through heavily infested zones of *G. swynnertoni* is frequently traversed by natives from Tanganyika who come to seek employment in Kenya. Motor-cars and lorries engaged in trading not infrequently use this road from and to Tanganyika Territory. One trader informed me that he caught a tsetse-fly on the Barkitabuk-Mbonget road, two miles from Barkitabuk. Game-hunters often visit this locality, and camp near water-holes or rivers. *G. swynnertoni*, it has been remarked, is abundant in the vicinity of some of these camps.

The southern boundary of the fly-infested area in the Colony is demarcated by

the territorial boundary line from the Kipaapaia Hills to the foot of the Isuria escarpment, west of the Engarare River. The western boundary may be indicated by a line drawn from where the escarpment enters Tanganyika, along the escarpment to the Lower Enderrit, on to the west of the Mara River, thence across to the east bank and to a distance of ten miles on that river from the Mara bridge at Long. $35^{\circ}12'$, Lat. $1^{\circ}8'$. The flies do not exist further north than a line drawn from the Mara River, across the Ol Arorok River, to about six miles south of Bardamat, and on to the point about six miles below Barkitabuk on the Kilimafeza road.

G. swynnertoni was found to be abundant on the Sianna River and the little streams running into it, the Ol Keju Longayanett, the Talek, and the Mara Rivers. It exists near the Ologimbai stream where the Kilimafeza road crosses the border into Tanganyika. At the base of the Sianna Hills and in Saaten, and at Geigoro water-hole and camp many flies were captured. At Ol Doinyo Burgoi, 24 males and 3 females were collected about 9 a.m. near the swamp and salt-lick. At that period I was camped on the Isuria escarpment. Olingendera, a headman, volunteered to take me down the escarpment to trans-Mara and stated that he could show me numerous tsetse-flies. He returned to his hut to smear his body with cow-fat, which was obviously a little rancid. On being asked as to the reason for this special precaution, he replied that tsetses would be attracted by the odour of the fat on his warm body. I told him to lead the safari and to keep about 100 yards in front. When we reached a belt of thorn-trees, I observed what seemed to be a swarm of flies trailing behind Olingendera. I hurried forward and made three rapid sweeps with a butterfly net, capturing 16 *G. swynnertoni*. A few more specimens were caught on the clothing of different members of the safari; but I am unable to say whether the rancid fat, with the odour of some iso-fatty acids, was actually responsible for the vast numbers attracted to the first individual person entering the bush.

In the presence of an abundance of game and in the absence of cattle, I found that *G. swynnertoni* very readily approached man and was attracted to moving vehicles such as cars and lorries.

I have already mentioned that *G. pallidipes* exists in the same area as *G. swynnertoni*, but apparently the former is not so numerous.

Discussion.

The distribution of species of *Glossina* in the Masai Reserve has frequently affected the administration of a tribe essentially pastoral and nomadic. The accounts of early investigations indicate that tsetse-flies did not inhabit areas of the reserve as large as they are now known to do. Their existence along river-courses has been reported from the time when it was arranged that the Masai should move to the one area—the present Masai Reserve. The presence of numerous cattle in Osero, in trans-Mara, along the Mogor and in the Ol Orokuti up to the years 1913 and 1914, and the fact that mortality among the cattle from any fly-borne disease in these areas was slight, indirectly supports the evidence that tsetse-flies were restricted to comparatively small zones.

MacClure & Monckton (1908) and Hemsted (1914) reported and illustrated fly-infested areas in the present Narok administrative district of the Masai Reserve. The former possibly confused the presence of East Coast fever in the valley of the Nasiandet River with trypanosomiasis. It was left to Anderson to record the particular species (*G. pallidipes* and *G. longipennis*) inhabiting the Nguruman valley, and to Hemsted and Woosnam to discover *G. fuscipleuris* on the Enderrit in trans-Mara.

Anderson found no tsetse-flies between the Uaso Nyiro and the Mara Rivers in 1913. Yet numerous *G. swynnertoni* and many *G. pallidipes* now range over Osero and parts of trans-Mara. Bearing in mind the habits of *G. pallidipes*, its comparative shyness of man, and the dry period during which the investigation was

conducted, it is reasonable to suppose that the species might have existed in this area in spite of its apparent absence. The readiness of *G. swynnertoni* to attack man and beast, however, and its present abundance throughout Osero, indicate that had it existed in this area at that time, reports of its presence would undoubtedly have been made.

It would seem, therefore, that these two species of tsetse have spread to a large extent since the arrival of the Masai in the extended southern reserve. The traces and remains of Masai bomas point to occupation of areas now uninhabited; and the progressive evacuation of villages with the advance of the tsetse and animal trypanosomiasis.

The record of a fly—"a species of *Tabanus*" which did not kill cattle in Osero, but drove them frantic by its bite—made by Hollis, is suggestive of *G. fuscipleuris*, on account of its voracity and painful bite. Some of the Masai residing on the Isuria escarpment brought me a specimen of this tsetse, and told me how it attacked their cattle at the salt-lick, causing the beasts to stampede; but they did not think that it transmitted any disease. *G. fuscipleuris* is not widely spread, but is common in river valleys.

G. pallidipes, it seems, must have existed in trans-Mara when Woosnam found *G. fuscipleuris*. Swynnerton definitely records it between the Isuria escarpment and the Mara River.

Without more detailed information it is not possible to explain the invasion of Osero and parts of trans-Mara by *G. swynnertoni*. It is likely that the species has spread from Tanganyika Territory where it occupied a large area of acacia woodland in East Mwanza. It may have been assisted by motor vehicles, by cattle, and by natives on trek from that territory. Game probably helped to widen the distribution and maintain the infestation. If this species has spread from Tanganyika, its eastern limit in the Mwanza district must have extended, although the boundaries demarcated by Swynnerton were, admittedly, not closely determined.

The existence of *G. swynnertoni* near the territorial boundary in trans-Mara and its proximity to the *G. palpalis* belt on the Mogor is disconcerting, in view of the possible infection of both species by human trypanosomes, as well as an extension of animal trypanosomiasis.

I have no data concerning that stretch of the Masai Reserve bordering on Tanganyika and extending from the Kipaapaia Hills to the Nguruman valley. The open plains of Serengeti in Tanganyika would discourage an advance of the fly from the main infected zone, but a narrow advancing belt may possibly occur from the region of Mount Olgoss to the *pallidipes* zone of the Nguruman, and ultimately to Lengutoto.

I have not been able to deal with the breeding-places of any of the species of tsetse in the Masai Reserve. A search for these is essential before discussing measures of combating the flies. The infested areas of Lorgasailik and Olmundus should not present an expensive campaign of eradication, even though they may be extensions of more extensive belts from the Nguruman and Chyulu respectively.

The customs and traditions of the Masai, however, enhance the difficulties in relation to the manual labour necessary in a campaign of this character; and their inherent dislike to cultivation renders maintenance of clearings a remote possibility.

In a reserve where arid or semi-arid areas are large, where East Coast fever exists on other smaller areas, and where additional areas are inhabited by tsetse, as shown above, grazing for stock must of necessity become scarce, at least periodically; and the people must be provided, as they are, with temporary occupation outside their legitimate reserve.

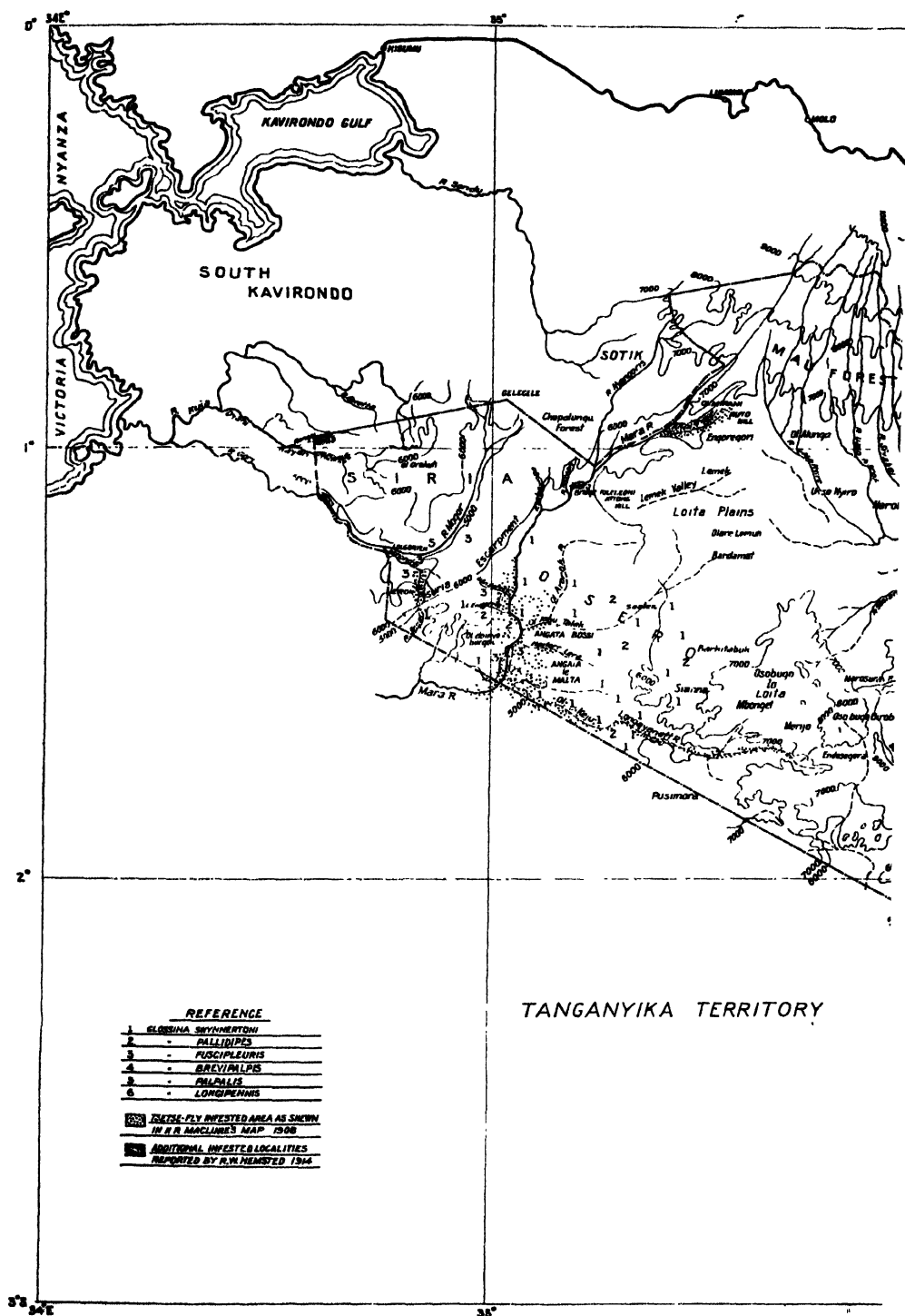
It will be noted that while the known tsetse-fly infestation in the Masai Reserve is serious, still further investigations are necessary in order to attempt effective improvements and the reclamation of fly-infested areas.

Acknowledgments.

I acknowledge, with gratitude, the assistance which I have received from Sir Guy A. K. Marshall, who has examined numerous specimens of these tsetse-flies; and from Mr. B. D. Burt, Survey Botanist, Department of Tsetse Research, Tanganyika, in the identification of numerous species of trees and bushes submitted to him.

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A NOTE ON THE CONCENTRATIONS OF TSETSE-FLIES.

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This subject has been discussed very fully by Dr. T. A. M. Nash and the writer in two recent papers (Bull. Ent. Res. **24**, 1933, pp. 135, 475-477). There is, however, one point which it is felt should be made clear. Dr. Nash states that the writer, "working in the Western Kondo fly-belt, finds the more normal type of obvious concentration. In the dry season tsetse become more numerous in *Berlinia-Brachystegia* woodland immediately surrounding 'vleis.' Owing to the small size of these 'vleis,' which are only about 75 yards across, the fly appears to an observer to be concentrated in them; in reality they are probably living in the shade of the surrounding weeds and fly out to attack the investigator. Passing through *Berlinia* woods in this country one finds fly more numerous on the edge of 'vleis,' probably because the trees are almost non-deciduous owing to sub-soil water."

Dr. Nash has not quite understood the writer's findings. During the dry season the fly (*Glossina morsitans*) do actually increase in the vlei or drainage valley itself, as distinct from the bordering woodland. This is apparent from the table on page 457 of the writer's recent paper, quoted above, and also from the work of Mr. D. B. Burt (see Bull. Ent. Res. **21**, 1930, pp. 512, 521). On page 503 of this last paper is a map* showing the sites ("Ecol. Stn.") at which Mr. Burt carried out routine fly catches. One catch was at a waterhole in the drainage valley or narrow vlei, one on the margin of the *Berlinia-Brachystegia* woodland surrounding it, and one well within this woodland. The following figures show that fly became more numerous, actually and relatively, in the vlei (Station 1) following the start of the hot, dry weather in August. In the margin of the surrounding woodland (Stations 2 and 3) fly admittedly increased at the same time relative to the numbers taken within the woodland (Station 4) But the increase in the vlei itself was proportionately greater.

Daily Catch of Flies taken by Mr Burt. (Total flies taken, 3,276)

	June	July	August	September	October
In vlei	3.8	4.4	10.6	25.3	20.4
In margin of woodland	3.2	4.0	9.7	14.5	16.9
In woodland	12.5	13.5	19.3	21.1	13.5

This table shows that fly really became more numerous in the vlei than in the woodland bordering it. It also supports the writer's contention that the increase of fly in the vlei in the hot, dry months is due, not to a search for better shade conditions, but to the fact that the vlei is a feeding-ground, and that the fly must visit it more frequently at the season when, as shown elsewhere (1933, pp. 466-473), the onset of hunger is hastened by hot, dry conditions.

While the increase of fly in the margin of the woodland at such times *may* be due to a search for better shade in less sharply deciduous conditions, it may also be due to increased traffic of flies to and from the vlei. That the second suggestion is more

* The scale of this map should be about 1"=1 mile, not 2" as given.

likely is indicated by the fact that flies in the margin of the woodland continue to show a higher Mean Hunger Stage and higher percentages of females and young flies (1933, p. 467) than do those well within the woodland.

Of course these statements must be regarded as in no way affecting Dr. Nash's and the writer's agreed view (1933, pp. 135, 476) that, in places where the vleis are very large and trees are scarce, fly may be driven back to their margins by the severe conditions obtaining in the height of the dry season.

OBSERVATIONS ON THE HIBERNATION OF PHLEBOTOMUS PAPATASII (DIPT.).

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The hibernation of *Phlebotomus papatasi* has been studied in detail by Roubaud. According to his observations there is no hibernation due only to external factors, but an asthenobiosis, which he defines as a resting stage independent of external factors and which occurs cyclically after a number of active generations as a consequence of an intoxication of the tissues of the larval organism by a surcharge of urates. According to Roubaud (1927, 1928a) this intoxication disappears during a prolonged resting stage at a low temperature, during which the metabolism of the larva is much reduced while excretion proceeds. After completion of this process of purification the larva is able to resume its normal course of development. The awaking from the resting stage is effected by a rise of temperature. There are, however, in his opinion, certain irregularities in the asthenobiosis of *P. papatasi* as compared with that of other insects which he has observed.

In another paper (1928b) Roubaud states that in *P. papatasi* an intoxication of the eggs may occur in the body of the insect, if oviposition is delayed, and that larvae hatching from such eggs incline to asthenobiosis.

In the following experiments an attempt has been made to determine whether in Palestinian *P. papatasi* there exists an asthenobiosis in the sense of Roubaud or a hibernation due to external (or other) factors.

In order to eliminate as far as possible all sources of error, it was necessary in the first place to establish the optimum conditions for the development of the species. A breeding method which gives uniformly good results under controllable conditions has been worked out by Adler and Theodor during the last seven years in connection with the study of the transmission of *Leishmania* by sandflies. A number of improvements in the original method have been published by Aschner (1927).

The method is briefly as follows:—After 2–3 blood meals one or more females (up to 20) are placed in very porous earthenware pots, which are kept in moist soil and covered with a glass funnel or with cloth and a lid. After oviposition the pots are observed until the first larvae hatch, and then a little food is added. The food should not be added before the hatching, because the very delicate young larvae entangle themselves in the mycelium developing before their hatching and die in great numbers. Fresh food is added in small quantities according to the activity of the larvae. After the pupation of some larvae no more food is given, as many of the hatching imagoes die in the mycelium which develops on the fresh food during pupation.

The food consists of 2 to 3 parts of finely sieved light soil, one part of ground dried rabbit faeces, and eventually a little powdered blood. Water is added and the ingredients are thoroughly mixed, until a thick paste is obtained. The mixture is then left standing for 2 to 3 weeks. During this time the evaporated water is replaced and the mixture stirred several times. The fermentation which occurs during this process kills most of the fungi which would otherwise impede the development of the larvae. The material is then dried and added in small quantities as a fine powder to the breeding pots.

The optimum temperature for development was found to be 30°C., but normal broods were also obtained at 27–28°C. with a correspondingly longer time of development. The optimum relative humidity in the breeding-pots was 85–95 per cent.

The amount of water added to the soil on which the pots stand has to be adjusted in such a way that there is no film of water, however thin, present in the pots, but that the walls of the pot and the food medium containing the larvae are saturated with moisture. The breeding-pots were kept in a large incubator at 30°C. A measured quantity of water was added regularly every 3rd or 4th day. The amount of water passing from the soil to the pots regulates itself very uniformly, so that temperature and humidity remained constant within very narrow limits throughout the whole duration of the experiments. The strict observance of these conditions made it possible to maintain a continuous supply of *P. papatasi*, which is easily induced to bite in the laboratory. *P. sergenti* and *P. caucasicus* were also bred by this method.

Continuous breeding of sandflies of the *major* group (*P. perniciosus*, *P. major*, *P. chinensis*) through several generations could not be carried out, as females of these species hatched in the laboratory either do not feed at all or do so only in very small numbers. The breeding conditions, however, were as favourable for these species as for *P. papatasi*. Species of the *minutus* group (*P. minutus*, *P. parroti*), which live usually on reptiles, were also bred by this method. A continuous breeding of these sandflies through several generations was not attempted, but it is probably easy, as bred specimens of these species gorged themselves regularly on geckos or other lizards.

Although the method described above gave uniformly good results in the majority of the breeding experiments, it is not perfect, and there were always pots which did not develop well, occasionally for no apparent reason.

Normal Course of Broods of *P. papatasi*.

The development of *P. papatasi* at 30°C. under the conditions described above in summer from the day the eggs are laid until the imagines begin to hatch lasted 30–37 days. The egg-stage lasted 6–8 days, the four larval stages 17–21 days, and the pupal stage 7–8 days. These figures are the average from several hundred broods. Calculated for all individuals of a generation at 30°C. an average duration of 36–40 days is obtained.

Normal broods are characterised by the hatching of the majority of the larvae within one or two days, activity of the larvae, uniform progress of the majority of the larvae from one stage to the next, and the hatching of the majority of the imagines within 6–10 days. Usually a few males hatch first and a few sandflies only hatch later than the majority. In such normal broods the percentage of imagines which hatch compared with the number of eggs laid is usually very high (75–85 per cent., often 100 per cent.).

Irregularity in the appearance of different larval stages and the hatching of isolated sandflies or of small batches over several weeks signify unfavourable conditions. In such broods larvae are found whose development is arrested over a relatively long period. The number of imagines hatching from such broods compared to the number of eggs laid is usually small.

The most susceptible periods in the course of development are the egg and the first larval stage. Unfertilised eggs are very often laid in the laboratory, a number of eggs die during their development and an additional number is killed by the parasitic fungus described by Adler & Theodor (1927). The fungus multiplies until it fills the infected egg and then emerges at one point from the egg which it envelopes completely.

The first larval stage is especially delicate. Growth of fungi or variations in humidity sometimes kill the greater part of the young larvae very quickly. In some pots 60–80 per cent. of the first stage larvae died under apparently good conditions for no discoverable cause: in the first winter generation (1933/34) 95 per cent. of the first stage larvae died. The 2nd and 3rd stages are much hardier, and in many cases a

number of 2nd stage larvae were observed without loss up to the hatching of the adults, while counted batches of 1st stage larvae completed their development much less frequently without losses.

The duration of the egg and pupal stages varied only within narrow limits and in normal broods the mortality was very low. When the development of the larvae was delayed (this phenomenon is described in detail later), the pupal stage was often much longer and the mortality in the pupal stage or in the act of hatching was much higher.

In one of his last papers Parrot (1931) states that in his broods of *P. papatasi* at 28°C. he could not find a definite period for the development, which might be protracted from 40 to 69 days and up to 92 days at 25°C. Further, in his broods the adults hatched not within a short space of time but in small groups over several weeks. Judging from observations in Palestine these facts indicate that the conditions in Parrot's broods were not optimal. It is of course impossible to compare results from one country with those obtained in another country, but it would be strange if the same insect were to behave so differently in two Mediterranean countries with such comparatively similar climates as Algeria and Palestine.

Hibernation.

In Palestine the sandflies disappear at the end of November, with the onset of the winter rains in the mountains (Jerusalem) and a few weeks later in the Jordan Valley (Jericho). At the end of October the average temperature is 19–21°C. and falls with the usually sudden onset of the rainy season with its strong western winds to 14–16°C. and less. The sandflies reappear in the middle of April in the Jordan valley and beginning of May in Jerusalem, when the temperature has risen again to about 20°C.

Broods which were kept at the beginning of the winter under out-of-door conditions developed slowly up to the 4th larval stage, and there the development proceeded no further, or the larvae died if they were too young (1st to 2nd stage). The hibernating larvae do not feed and their intestine is usually quite empty. They are motionless until the middle of April to the beginning of May, when they resume their activity, start feeding, pupate and hatch. In some broods resting larvae may be found in small numbers in summer and in greater numbers in autumn, when the external conditions give no cause for hibernation. The significance of this phenomenon is discussed later.

In broods kept under out-of-door conditions hibernation could be interrupted by several methods. The medium containing the larvae was sieved out through wire netting of about 1 mm. mesh and the larvae collected, then fresh food was added and they were placed at 30°C. ; usually a few days later a number pupated. In some cases the mechanical stimulus of the sieving alone, sometimes the rise of temperature alone, sufficed to reactivate the larvae, but in other broods all methods, alone or combined, were without effect.

If this hibernation in *P. papatasi* is an asthenobiosis as conceived by Roubaud, *i.e.*, an intoxication of the larval organism, it should take place under any condition and at any temperature after a number of active generations. If it is, however, a hibernation dependent on external conditions it may be possible to influence it to a smaller or higher degree by a change of these conditions.

The most suitable materials for such an investigation are the sandflies of the last summer generation, for after 4 to 5 active summer generations an inclination to asthenobiosis should be especially marked. It was therefore attempted to continue active broods, at a time when sandflies would normally hibernate, by maintaining the conditions under which they usually develop actively.

The optimum relative humidity (85–95 per cent.) had to be observed very accurately, as the sandflies are very sensitive to variations in humidity within very narrow

limits, though much less so to variations of temperature. They were kept at 30°C., a temperature which had proved optimal for the summer generations.

History of the Broods.

First Winter Generation, 1931-32.

Sandflies of the last generation were caught in the middle of November, fed twice or three times and placed individually in small breeding-pots. From 30 females 22 egg-layings of 15-50 eggs each were obtained. In these broods, which began between the 15th and 24th November, the majority of the adults hatched between the 3rd and 17th January, *i.e.*, between the 46th and 56th day of development. Only a few hatched earlier or later. The average duration of development calculated for all broods was 51.5 days, considerably longer than in summer (36 to 40 days). A greater number of larvae hibernated only in two pots (in No. 15, 8 adults hatched and 11 larvae hibernated and in No. 16, 24 adults hatched and 10 larvae hibernated). In the other broods either all the larvae developed actively or 1 to 3 larvae remained hibernating. Altogether 189 adults hatched and 36 larvae remained in hibernation. Of these 36 larvae 11 pupated during the winter and 7 adults hatched, the 4 remaining pupae and the rest of the larvae died. In 4 broods nearly all larvae died in the first stage and only a few attained the 4th stage, but did not complete their development.

Second Winter Generation, 1931-32.

A number of females of the previous generation were again placed individually in pots and 27 layings were obtained; 12 broods started on the 3rd (of which one did not develop) and 15 between the 10th and 12th January (of which 8 did not develop). This was possibly due to the fact that the second group of broods originated from females which hatched singly or in small batches and a number probably remained unfertilised. (Copulation generally takes place in the breeding-pot before the first blood-meal.) The females laid eggs 8-14 days after hatching; the egg-stage lasted 7-11 days and the pupal stage 6-11 days, periods which approximate to normal summer development. The development of the larvae was distinctly prolonged, as in the preceding generation. Only a few larvae developed in 23 to 25 days, the majority required 30 to 40 days and a few as much as 60 days. The average duration of the development for the whole generation was 46.9 days, also distinctly longer than in summer. Altogether 105 imagines hatched and 30 larvae remained in hibernation, of which a number pupated and hatched without any change of conditions and the rest died. In 6 pots a great percentage of the eggs did not hatch and the majority of the first-stage larvae died, so that only one larva in each pot attained the 4th stage. All these larvae pupated after a very prolonged development (58 to 73 days) and died during pupation. These pots are examples of development under *a priori* unfavourable conditions (belated hatching of the females, damage by fungus,? under-population, etc.).

Third Winter Generation, 1931-32.

From females of the preceding generation 17 batches of eggs were obtained in the beginning of March; 9 of these broods developed actively and were equal in every respect to normal summer generations or showed a moderate prolongation of development. In two pots development was distinctly prolonged and six broods did not develop at all (unripe or unfertilised eggs). The average duration of development for the whole generation was 47 days, as in the preceding generation. In all, 134 imagines hatched and 46 larvae remained in hibernation, of which 18 hatched between the 72nd and 90th day of development and the rest died.

The mortality was only 10 to 15 per cent. in two pots, but in most of the other pots it was very high in the first larval stage. High mortality and prolongation of development did not seem to be correlated, as pots with a low mortality showed a normal or

prolonged development as well as pots with a high mortality. Only one pot showed a marked inhibition of development at the 3rd larval stage (the majority of the larvae had died in the first stage). Only two imagines hatched on the 76th and 79th day of development and the other larvae died.

At this stage the continuous breeding had to be interrupted.

Series A, 1932-33.

A new series of broods was started in August 1932 with wild females caught in Jerusalem. From the breeding-pot into which several females were placed, 72 sandflies hatched and 16 larvae remained in diapause, of which 7 hatched during January and March 1933 and the rest died. The average duration of development was 49.9 days, a considerably longer time than in the early summer generations.

First Winter Generation (Series A).

This generation was commenced about the middle of October with females of the August generation. From 8 broods started with single females, 5 developed normally and gave 71 sandflies and 36 larvae hibernated. In 3 pots all larvae remained in hibernation. Unfortunately the hibernating larvae were all killed by accident. The average duration of the development was 43.8 days, *i.e.*, only slightly longer than in summer.

Second Winter Generation (Series A).

Ten egg-layings were obtained from females of the preceding generation between 20th November and 7th December. Only 14 sandflies hatched and 94 larvae remained hibernating. In 4 pots nearly all the larvae hibernated. They were also killed by the same accident as the larvae of the preceding generation. The average duration of development was 57 days. As a whole, the inclination to hibernation and the prolongation of development was most apparent in this generation (with the exception of Control Generation no. 3 of 1933-34).

Third Winter Generation (Series A).

Four egg-layings were obtained from females of the preceding generation, of which two were laid on 2nd March and two on 17th March; 140 sandflies hatched from these pots and only 3 larvae remained hibernating, of which two hatched on 10th May and the last one died. The average duration of development was 43.5 days. In contradistinction to the preceding generation the development was completely active and the duration only slightly longer than in summer.

First Summer Generation (Series A).

Fourteen broods were started with females of the preceding generation, which laid their eggs between 20th April and 4th May. From these 271 sandflies hatched and 22 larvae remained in diapause, of which 13 hatched within 1 to 2 months and the rest died. The average duration of development was 36.1 days, *i.e.*, precisely as in other active summer generations. The time during which this generation developed coincides with that of the first natural summer generation.

Second Summer Generation (Series A).

In 25 pots were placed females of the preceding generation, which laid their eggs between 1st and 10th June. From these pots 490 sandflies hatched and 36 larvae (*i.e.*, 7.2 per cent.) remained in diapause. Only a few of these larvae pupated and 3 hatched. The rest remained in diapause in spite of stimulation and died. The average duration of development was 37.8 days. All pots developed normally.

Third Summer Generation (Series A).

In 14 pots were placed females of the preceding generation of which three laid a second batch of eggs (two of these second batches developed normally and from the third, which

contained only 7 eggs, one male hatched on the 63rd day and the remainder died). The eggs were laid between 11th and 18th July, and 305 sandflies hatched and 42 larvae (*i.e.*, 12.1 per cent.) remained in diapause, of which 16 hatched after stimulation. Of the rest some remained in diapause and died, some pupated and died as pupae or in the act of hatching. The average duration of development was 40.3 days. All pots developed normally.

Fourth Summer Generation (Series A).

In 14 pots were placed females of the preceding generation, which laid their eggs between 27th and 28th August. From these 224 sandflies hatched and 84 larvae (*i.e.*, 27 per cent.) remained in diapause. After stimulation only 3 sandflies hatched and the rest died—a few in the act of hatching, some as pupae, and the rest as larvae; 12 pots developed normally, but two showed a marked prolongation of development (pot no. 218, 65.4 days; pot no. 220, 63.1 days). The average duration of development calculated for all 14 pots was 54.12 days, for the 12 normal pots only it was 50.7 days, even that being a marked increase compared with early summer generation. The percentage of hibernating larvae was especially high in pot no. 218 (21 larvae out of 52).

First Winter Generation, 1933–34. (Series A).

In 28 pots were placed females of the preceding generation which laid their eggs between 20th and 26th October, 1933; 3 females laid second batches of eggs between 25th and 30th October. There was a very heavy mortality in the first larval stage. From about 680 eggs, which nearly all hatched, only 31 larvae attained the second stage, 28 the third, 14 the fourth, 8 larvae pupated, 6 sandflies hatched, 3 larvae remained hibernating and died. The average duration of development of the 6 sandflies was 73.8 days. The reason for this extraordinarily high mortality is not clear.

Second Winter Generation, 1933–34. (Series A).

One of the 3 females of the preceding generation laid 17 eggs on the 25th January 1934. One male hatched on the 73rd day and 10 larvae remained in diapause. Of these six hatched between 2nd May and 9th June, and the rest died.

These last two (or three) generations show a rather longer duration of development than corresponding generations in other years. They are also not normal in other respects (*e.g.*, the high mortality in the First Winter Generation of 1933–34). It is therefore perhaps advisable to note just their general tendency to longer development but to omit the numbers in calculations.

Apart from the series of broods described above, two more series were put up. The pots were started with wild sandflies caught in October (Series B) and in the beginning of December 1932 (Series C). About 20 females were put into each pot. This generation corresponds in season to the first winter generation of Series A. All pots developed actively, 1,021 sandflies hatched in Series B and 1,458 sandflies in Series C. A good number of larvae remained in hibernation, but their number was not noted. The average duration of development was 50.6 days in Series B and 62 days in Series C.

Second Winter Generation (Series B).

Ten broods were started with females of the preceding generation, which laid their eggs between 19th and 24th February. From these 156 sandflies hatched and 23 larvae remained in hibernation, of which 19 hatched during May and the remainder died. Average duration of development 41.7 days. All pots developed actively in a time almost exactly corresponding to normal summer development, while in the corresponding generation of Series A the inclination to hibernation was very strong.

Third Winter Generation (Series B).

In 4 pots were placed females of the preceding generation, which laid their eggs

on 9th April, and 121 sandflies hatched between 12th and 30th May. Only 8 larvae remained in diapause, of which six hatched at the end of June. Average duration of development 40.6 days.

Second Winter Generation (Series C).

In each of 15 pots were placed several females of the first winter generation (started in December) between 5th and 12th January, and 704 sandflies hatched between 15th February and 19th March, and 51 larvae remained in hibernation. Average duration of development 48.8 days.

Third Winter Generation (Series C).

In 14 pots were placed single females from the preceding generation, of which four laid their eggs on 26th February and 10 on 26th March. From these 256 sandflies hatched, 34 from the first 4 pots between 2nd and 12th April, and 222 from the other 10 pots between 4th and 16th May. Only two larvae remained in diapause from the first 4 pots and none in the other 10 pots. One of these larvae hatched on 9th June and the other on 8th August. Average duration of development 40.7 days, as in the corresponding generation of Series B.

Controls.

As it seemed possible that the continuous breeding under artificial conditions, which, however good, were probably different from natural ones, might have influenced the development of the sandflies, pots were put up with wild caught females during the later part of summer and autumn. Generally these generations behaved exactly like the corresponding generation of the continuous breeding.

Control Generation No. 1.

Sandflies were caught on 24.vii.33, and 8 females laid their eggs between 27th and 30th July. From these 328 sandflies hatched. In 6 pots nearly the full number of eggs developed and hatched. Only in 1 pot (no. 205) 16 larvae out of 88 remained in diapause. Of these larvae 11 hatched after stimulation and the remainder died. The average duration of development was 45.8 days (pot no. 205, 53.8 days). This generation falls between Summer Generation 3 and 4 of Series A and its duration of development is also intermediate between that of these two generations (40.3 and 54.2 days respectively).

Control Generation No. 2.

Sandflies were caught on 27.ix.33, and 9 pots were put up. In 2 pots the eggs did not hatch and in 2 pots nearly all the first stage larvae died; 40 sandflies hatched and 18 larvae (*i.e.*, 31 per cent.) remained in diapause, of which 7 hatched after stimulation and the rest died. The average duration of development for all pots was 72.5 days, but this included pot no. 230 which took 100.43 days; excluding this pot, the average duration was 66.6 days. This generation corresponds in season to Summer Generation 4 (Series A), which also showed a marked prolongation in development (54.12 days) and an increased percentage of hibernating larvae (27 per cent.).

Control Generation No. 3.

Sandflies were caught on 16.xi.33 and 4 pots put up. The eggs were laid on 21st and 22nd November. Only 9 sandflies hatched up to the end of January, and 66 larvae (*i.e.*, 89.2 per cent.) remained in diapause. Average duration of development 61.5 days. This generation corresponds rather accurately to the First Winter Generations of 1932-33 and 1933-34, with their marked prolongation of development and high percentage of hibernating larvae (87 per cent.). The hibernating larvae started pupating at the beginning of April; 13 sandflies hatched in April and 20 in May. Of the remaining 33 larvae about 10 pupated and died and the rest died as larvae.

Control Generation No. 4.

From earlier observations it appeared that overcrowding of the pots may have an influence on the development of the larvae and on the appearance of diapause (Late Summer Generation of 1932, First Winter Generation Series B and C of 1932/33).

Of the Third Summer Generation 11 sandflies were put together and laid 150 to 200 eggs between 29. and 31.viii.33 (pot no. 223). The development of this pot was very markedly delayed as compared with the single pots of the same generation. Whereas the majority of the single pots started hatching on the 46th day, the first sandflies from pot no. 223 hatched on the 60th day. Its average duration of development was 80.5 days as compared with 54.12 days for the single pots and 65.4 and 63.1 days, respectively, for the two slowest pots of this generation; 64 sandflies hatched from this pot and 71 larvae remained in diapause. Of these 35 were kept at 30°C. and 36 at room temperature. Of the lot kept at 30°C. 19 hatched in irregular intervals between 10.xii. and 30.iv. and the rest died. Of the lot kept at room temperature 15 had died on 15.iii.34. The remaining 21 larvae started pupating on 6th May and all hatched by 6th June.

Discussion of Results.

From the broods described above it appears that it is possible to breed *P. papatasi* at 30°C. during the winter without hibernation and that hibernation is induced mainly (but not entirely) by low temperature.

TABLE I.

Percentage of resting larvae in the various generations: a, percentage of larvae resting after the conclusion of the normal hatching period; b, percentage of larvae remaining in the resting stage after stimulation of the resting larvae.

Generation	Season 1931-32			1932-33			Controls
				Series A	Series B	Series C	
Late Summer ...	August-September	a b	%	% 18.2 10.0	%	%	(1) 4% 1.2%
Autumn ...	October-December	a		33.6			(2) 31%
Winter 1 ...	November-January	a b	16.0 11.0	87.0			(3) 89.2%
Winter 2 ...	January-March	a b	21.6 15.7		12.8 2.2	6.7	
Winter 3 ...	March-May	a b	25.5 15.5	2.1 0.7	6.2 1.6	0.77 0.39	
Summer 1 ...	May-June	a b		7.5 3.0			
Summer 2 ...	June-July	a b		6.8 6.3			
Summer 3 ...	July-August	a b		12.1 7.6			
Summer 4 ...	September-November	a		27.0			

Although the appearance of hibernation seems thus to be due mainly to external factors, several observations during the course of the experiments indicate that the

cycle of summer activity and resting stage in winter is not only due to external factors, but that there exist other, perhaps hereditary, factors which influence this cycle in *P. papatasi* to a certain degree.

As described above the number of hibernating larvae increases gradually in the later summer generations, although the climatic conditions at this time of the year provide no cause for hibernation. There is always a certain number of resting larvae during the early summer in active generations (up to 12 per cent.), but this number increases up to 30 per cent. in autumn and is most marked in the first winter generation, when sometimes 90 per cent. of the larvae remain in the resting stage (Table I). During autumn and in the first winter generation the larvae are also much more resistant to stimulation than in the early summer generation, when sometimes up to 90 per cent. of the resting larvae could be induced to pupate by sieving and addition of fresh food. The mortality in the larvae which pupated after stimulation was much higher in the autumn and winter than in the early summer generations.

TABLE II.
Average duration of development in days at 30°C.

Generation	Season	1930	1931-32	1932-33			Controls
				Series A	Series B	Series C	
Late Summer	August-September	(a) 41.8 (b) 35.0		(a) 49.9 (b) 38.0			
Autumn	October-December	(a) 45.9 (b) 36.0		(a) 43.8 (b) 38.0			
Winter 1	November-January		(a) 51.5 (b) 41.0	(a) 57.0 (b) 36.0	(a) 50.6 (b) 36.0	(a) 62.0 (b) 36.0	
Winter 2	January-March		(a) 46.9 (b) 40.0		(a) 41.7 (b) 34.0	(a) 48.8 (b) 38.0	
Winter 3	March-May		(a) 47.0 (b) 36.0	(a) 43.5 (b) 35.0	(a) 40.6 (b) 33.0	(a) 40.7 (b) 33.0	
Summer 1	May-June			(a) 36.1 (b) 30.0			
Summer 2	June-July			(a) 37.8 (b) 30.0			
Summer 3	July-August			(a) 40.3 (b) 30.0			
Summer 4	September-November			(a) 54.12 (b) 43.0			Control No. (1) (a) 45.8 (b) 35.0 Control No. (2) (a) 72.5 (b) 36.0
Winter 1 1933-34	November-January			(a) 73.8 (b) 65.0			Control No. (3) (a) 61.5 (b) 51.0

(a) Average duration of the generation.

(b) First day of hatching.

Further, the average duration of development increased gradually during the later summer generation; it was most marked in the first winter generation and then gradually decreased. The third winter generation generally showed little or no prolonged development (Table II).

Finally, some larvae which remained in diapause throughout the winter, although they were kept at 30°C., pupated at exactly the same time as those which had been kept as controls under out-of-door conditions or at room temperature throughout the winter, after the outside temperature had risen sufficiently and the first sandflies started to appear in Jerusalem (beginning of May).

The same phenomenon was observed in 1934. Several pots of control generation no. 3 kept at 30°C., which had been hibernating for 3 to 4 months, started pupating in April; 50 per cent. of the larvae hatched during April and May and about 15 per cent. pupated but died as pupae. At about the same time control no. 4 (pot no. 223b) which was kept at room temperature during the whole winter from 16.xi.33 onwards, started pupating and all the larvae which had survived up to the middle of March (21 out of 36) hatched in May and the first days of June (average temperature in the laboratory 22°C.).

These three features, the gradually increasing appearance of hibernating larvae in autumn, the gradually increasing duration of the late summer and early winter generations, and especially the pupation in spring independently of external factors, indicate that hibernation, apart from external factors, is also determined by cyclical factors. This is also indicated by the greater difficulty in stimulating resting larvae to resume their activity in winter and the great mortality in individuals which pupated after a long resting stage in winter. Breeding over several years and an exact analysis are of course necessary in order to determine whether these phenomena are a regular feature of the annual cycle or are perhaps accidental. The observations recorded above, however, show that the phenomena recurred in a very similar way in the three years over which these observations were extended.

It is difficult to explain the prolongation of active development in winter as caused by external factors only, and especially the simultaneous pupation of hibernating larvae kept under out-of-door conditions and larvae kept at 30°C. The whole complex of external and cyclical (? hereditary) factors is probably necessary to cause hibernation, as the above observations indicate that temperature alone cannot account for all the phenomena recorded. If the hibernation of *P. papatasi* were dependent on external factors (temperature) only, sandflies in Jericho should appear six weeks before they actually do.

A number of observations indicate that the resting stage of the larvae may also be caused by unfavourable conditions only, e.g., lack of food, overcrowding of the breeding pots, under-population, too high content of excreta in the food medium, etc. That some of these factors are responsible for the appearance of resting larvae is suggested by the fact that the percentage of resting larvae during the summer is much higher in overcrowded pots than in normally populated ones. Control no. 4 also shows that the duration of development and the percentage of hibernating larvae is much higher in a pot in which a great number of larvae develop together than in pots containing a single larva. Under-population also seems to have a similar effect. Pots with only a few larvae generally developed more slowly than pots with 30-40 larvae in a food area of 12.5 ccm. Larvae of the early stages generally die under unfavourable conditions, and therefore only fourth stage larvae, which seem to be especially adapted to survive under such conditions, are observed in this state. This inhibition of development by unfavourable conditions indicates that an inclination to diapause exists latently in all generations and that the appearance of diapause may be induced by a variety of factors apart from temperature and cyclical factors.

Resting larvae may be observed in greater or smaller numbers (2 to 12 per cent.) in many pots throughout the year, even in active broods in early summer otherwise developing quite normally. A certain number of these resting larvae may be induced to pupate by sieving and addition of fresh food, but some resist all stimulation and die without any further development.

The percentage of such resting larvae is not constantly higher in winter than in summer. In some winter generations (especially in Series A) it was much higher than in summer, but as in parallel winter generations of Series B and C it was even lower than in active summer generations, this cannot be considered as a feature of hibernation.

This occurrence of resting larvae throughout the year shows that conditions which seem to be optimal are actually not so, and that there are other as yet unknown factors which determine the development of the larvae. It would be perhaps more justifiable to look for an intoxication as a cause of this phenomenon than as a cause of hibernation. The simultaneous occurrence of hibernation and of this inhibition of development by unfavourable conditions, or the interpretation of the latter as hibernation, have caused a number of rather puzzling statements.

It is important in this connection to mention the experiments of Cousin, who was able to breed *Lucilia sericata*, a heterodynamic insect according to Roubaud, through about 50 generations without the appearance of diapause. Cousin proved that the appearance of diapause in *Lucilia sericata* depended on unfavourable external conditions only and that no diapause occurred under optimal conditions. On the other hand, diapause could be induced by variation of certain external factors, *i.e.*, temperature, humidity, food, light, etc. Roubaud tried to explain these results by assuming that a selection of active individuals had taken place in the course of 50 generations.

I have tried to eliminate this possibility for *P. papatasi* by using not only one continuous strain but several others in addition, which started from different wild batches, but the phenomena described above occurred in all series in the same way. On the contrary, instead of getting a wholly active population by selection, their inclination for hibernation increased considerably after one and a-half year's continuous breeding, and the phenomena described occurred also in the control generations from wild sandflies.

Roubaud's terminology cannot very well be applied to *P. papatasi*, as we have clear evidence of an intermediate state between "heterodynamy" and "homodynamy". In *P. papatasi* hibernation depends mainly on external factors, but cyclical factors certainly exist which modify the phenomena of hibernation to a certain extent. These cyclical factors are possibly hereditary, but further work is needed in order to determine their exact nature.

The occurrence of resting larvae throughout the year in varying numbers, which has already been noted by Roubaud, is almost certainly due to unfavourable conditions only. Asthenobiosis, as defined by Roubaud, is a cyclical phenomenon with a fixed position in the animal cycle. The irregular appearance of resting larvae throughout the year is probably the best argument against the interpretation of this phenomenon as asthenobiosis. Roubaud's later observations that asthenobiosis in *P. papatasi* may disappear after long duration without reactivation by heat also suggests that he was dealing with larvae in a resting stage caused by unfavourable conditions rather than with hibernating larvae.

According to Roubaud's observations, larvae which hatched from eggs whose deposition had been delayed showed an especially marked disposition to asthenobiosis. He assumed an intoxication of the eggs in the body of the sandfly as the cause of this phenomenon. He observed that the progeny of 5 females that had laid their eggs up to 6 days after the first bloodmeal was active, while that of 6 other females that laid their eggs after the 6th day was partly asthenobiotic. If such an intoxication of the eggs occurs in the body of the sandfly, it is difficult to understand why it should affect only part of the eggs, although all eggs develop simultaneously and are presumably subject to the same conditions in the body of the insect.

My observations on *P. papatasi* in Palestine do not confirm Roubaud's view that delayed oviposition may cause asthenobiosis. All sandflies used in the broods

recorded above were fed the day after hatching. Oviposition took place usually on the 8th day after hatching, in the majority 10 to 12 days after hatching, and sometimes even later. The occurrence of resting larvae could in no case be connected with an especially long interval between hatching and oviposition. In the third winter generation oviposition took place sometimes 11 days, but mostly 14 to 21 days, after hatching and the 3 specially active broods of this generation were the progeny of females which had laid their eggs 17 to 18 days after hatching; while the only brood of this generation which was completely inactive originated from a female which had laid its eggs 7 days after hatching. Two more inactive broods originated from females which had laid their eggs 13 to 14 days after hatching, also a shorter interval than in a number of active broods.

Although an intoxication of the eggs in the maternal organism probably does not occur, the individual history of the mother insect is not without influence on the development of the next generation. Sandflies from normal active broods which feed regularly generally give a more numerous and vigorous progeny than sandflies whose hatching is delayed and which may have suffered as larvae under unfavourable conditions.

Mortality.

As mentioned above the mortality is highest in the first larval stage. There was no markedly higher mortality in the winter generations than in the summer generations. The number of eggs laid in each pot was counted and the number of adults

TABLE III.

Mortality in the various generations.

Mortality			0-10%	11-30%	31-50%	51-90%
Winter gen. 1	Series A	...	3	3	1	—
Winter gen. 2	Series A	...	3	—	—	3
Winter gen. 3	Series A	...	3	1	—	—
Summer gen. 1	Series A	...	9	2	1	3
Summer gen. 2	Series A	...	12	6	5	1
Summer gen. 3	Series A	...	3	6	2	6
Summer gen. 4	Series A	...	1	5	3	5
Winter gen. 2	Series B	...	4	—	5	1
Winter gen. 3	Series B	...	3	—	1	—
Winter gen. 3	Series C	...	9	1	2	2
Control gen. no. 1	...	...	7	—	1	—
Control gen. no. 2	...	...	—	1	1	5
Control gen. no. 3	...	...	3	—	—	1

hatched plus the number of resting larvae deducted. The broods with no mortality at all and those with a mortality up to 10 per cent. were taken together, as there is always the possibility of overlooking some eggs, and this fact in the small numbers with which we are concerned might account for inaccuracies up to 10 per cent. (Table III).

There is a remarkably high mortality of larvae kept at 30°C., both in hibernation and in the resting stage, caused by unfavourable conditions. Hibernating larvae of *P. perniciosus* nearly all died when they were kept at 30°C. (Adler & Theodor 1931). A sudden transfer from low to higher temperature generally induced a number of larvae to pupate, but many died during pupation and others in the act of emerging. This behaviour of the larvae may be considered as a stimulation by heat, and on the other hand as injury by heat. The metabolism of the hibernating larvae is apparently different from that of actively developing larvae, and the sudden rise of temperature is apparently unfavourable for the resting larval organism.

Some observations of Martini and Hecht on larvae of *Anopheles bifurcatus* show similar phenomena. The duration of development in winter was three times as long as in summer, although the larvae were kept at the same temperature in winter and summer, and the mortality of the hibernating larvae which were kept at a high temperature was about 80 per cent. Martini also observed that larvae of *A. bifurcatus* kept at 20°C. in winter came to the surface only every two hours, instead of every five minutes, as in summer at the same temperature. According to Martini this observation indicates "a profound change in the oxygen requirements, as in the hibernation of mammals."

The records on the occurrence of hibernation in *Phlebotomus* vary considerably for different countries. In Paris Roubaud observed no hibernation in *P. perniciosus* from Tunis, while Adler & Theodor in Sicily and Malta found a hibernation of *P. perniciosus* analogous in every respect to that of *P. papatasi*. Parrot did not observe hibernation of *P. papatasi* in Algiers, while Roubaud working in Paris observed hibernation of *P. papatasi* from Tunis, and according to the observations recorded above *P. papatasi* does hibernate in Palestine. Similarly some Anophelines hibernate in Europe, while the same species in Palestine has no complete hibernation but awakes occasionally in warm weather. It is, of course, impossible to compare observations made under different climatic and laboratory conditions. The scanty observations, however, on the hibernation of *Phlebotomus* in different countries, together with the observations recorded above, make it rather certain that temperature is the deciding external factor causing hibernation.

A high relative humidity is the fundamental factor for the existence of *Phlebotomus* under any conditions, whether in active development or in hibernation, and therefore its influence on the phenomena of hibernation can be eliminated.

Summary.

Hibernation of *P. papatasi* in Palestine is primarily caused by low temperature, but cyclical (? hereditary) factors exist which modify the phenomena of hibernation to a certain extent, as indicated by the following facts.

1. Occurrence of a gradually increasing number of resting larvae during autumn, with a maximum of hibernating larvae in the first winter generations.
2. A gradually increasing prolongation of development during the late summer generation, with a maximum duration of development in the first winter generations in larvae kept at 30°C.
3. The pupation of hibernating larvae kept at 30°C. in spring at the same time as of larvae kept in out-of-door conditions during the winter.

There is always a certain number of resting larvae (2 to 12 per cent.) throughout the summer in otherwise active broods. This inhibition of development shows that a latent inclination to diapause exists in all generations, and that diapause may also be brought about by unfavourable conditions.

No relation could be found between the interval between hatching and oviposition and asthenobiosis.

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A REVIEW OF THE SPECIES OF THE SUBGENUS *TRIRHITHRUM*, BEZZI (TRYPETIDAE, DIPTERA).

By H. K. MUNRO, B.Sc., F.R.E.S.

Many years ago Bezzi realised that the species placed in the genus *Ceratitis*, MacL., needed division into smaller groups. Among those he first delimited, *Carpophthoromyia*, Aust., may well be retained as a genus, but most of the others, *Pardalaspis*, Bez., *Perilampus*, Bez., *Trirhithrum*, Bez., etc., have hardly more than subgeneric value. It is therefore proposed to study all the species concerned in order to discover the true limitations of the groups; and also with a view to stabilising the species themselves for a further study involving dissection of specimens. The last point is of some importance because more detailed work on the morphology cannot be carried out at all satisfactorily until one is quite sure of the specific identity of the specimens used. Further, as the dissection of insect types may be undesirable and few institutions, if any, would allow it to be done, it becomes essential to have specimens critically compared with types, and until this is done, there must always remain some element of doubt in identifications. This paper is thus a beginning of a series on a preliminary study of the subgenera of *Ceratitis*.

TRIRHITHRUM, Bez.

Bezzi 1918, pp. 217, 236; 1920, p. 222; 1924a, pp. 75, 105; 1924b, pp. 472, 483.
Hendel 1931, p. 2.

The genotype is *Ceratitis nigra*, Graham, and Bezzi's diagnosis is to be found in the tables published by him at various times.

The most striking structural feature is the short head with its strongly developed bristles. The plumosity of the arista is also of value, but Bezzi himself included species with a bare arista. Of these two, *Ceratitis lycii*, Coq., 1901, and *Trirhithrum minimum*, Bez., 1924, may definitely be excluded from *Trirhithrum*. In both the arista and frons are bare, the head is not short, and there is a well-developed grey-dusted pattern on the dorsum of the thorax. They may perhaps be placed in Hendel's subgenus *Trirhithromyia* (Hendel, 1931, p. 2) but this will be considered later. *Ceratitis albomaculata*, v. Röd., is a *Trirhithrum* in spite of the bare, or rather, minutely pubescent, arista. In *Trirhithrum litteratum*, Mro., the arista is shortly plumose, so that because of this and other characters a new subgenus does not seem warranted, although the wing-pattern is atypical.

All the species are black, or blackish, and this, taken with various other characters, may be considered of subgeneric value. The coloration of the scutellum falls into two main groups, those in which it is more or less broadly white at the base and black apically, and those in which it is black. In *T. inscriptum* it is divided into quadrate areas by yellow lines, as is usual in *Pardalaspis*, while in *T. nitidum* the black margin is partly and in *T. litteratum* entirely divided by a pair of short yellow lines. White (or yellow) markings on the thorax are generally absent; there may be a streak along the upper edge of the mesopleura, but occasionally the latter may be largely white, as also, rarely, the humeri. With the increase of white markings on the thorax there seems to be some transition towards *Perilampus*, Bez.

The pubescence (short appressed hair) on the dorsum of the thorax may be black or white, sometimes yellowish. When it is black it is usually strongly shining brown. The colour has been taken to be of some importance in separating groups of species. However, with the accumulation of material and the discovery of new species, the

decisiveness of characters often becomes less—such seems to be the case here. In two of the new species described the colour of the pubescence is different in the sexes. In *dimorphum* it is black in the female and yellowish in the male, whereas in *brachypterum* it is black in the male and white in the female.

In cases like this, where a character previously used to separate groups of species is found to vary within a species, the difficulty is to decide that specimens of opposite sexes really belong to each other. One usually has some hesitation in putting together an odd male and an odd female, especially if the localities from which they come are widely separated. At the same time, careful comparison of other characters will remove most doubt as to the correctness of the decision. The only alternative would be to name them as separate species when there are differences in secondary sexual characters unless indubitable evidence can be obtained by rearing specimens from known parents—seldom a practicable proposition.

Grey dust is sometimes very slightly developed on the dorsum of the thorax, seldom noticeable enough to form a pattern. Care should be taken to note, from the general appearance of the specimen, whether there is any reason to suppose the grey dust may have been obliterated. This applies particularly to the grey-dusted markings on the abdomen. Here they are normally absent in some species, but in others appear so on account of discoloration. If specimens are greasy, they should certainly be washed in ether before examination.

The scutellum itself is smoothly rounded, there being no trace of the so-called "keel" referred to by Bezzi under *Perilampus*.

The legs are normal and not ornamented, except in the males of two species, *T. facetum* (End.), in which the middle tibiae are feathered, and *T. inauratipes*, Mro., in which the front femora are thickened and ornamented with long, bushy, golden hairs.

In regard to the wing-pattern, some remarks may be made about the terms used by Bezzi in describing the various "bands." While it may be possible to select more suitable words for the purpose, it is not proposed to change them with the exception of the "middle band" for which "medial band" seems better. The use of the word "middle" is not recommended, as it is somewhat indecisive and also the cubital is as often as not the only crossband present, and it is then quite logically the "middle" band. Further, the term "humeral band" is added. There are thus the following:—

Humeral band: from the humeral cross-vein across the base of the wing towards the anal cell. In *Trirhithrum* it is not often developed separately; mostly it extends to the hind margin of the wing, where it is broadly confluent with the basal band; above, it is separated by a hyaline costal indentation, more or less numerous basal hyaline streaks being present, or it may be wholly joined to the basal.

Basal band: from the stigma to, or nearly to, the hind margin of the wing and more or less confluent with the humeral. Bezzi refers to it also as the "anal band."

Marginal band: along the costa from the stigma and largely filling the marginal and submarginal cells. It is not disconnected from the basal in species of *Trirhithrum*. Bezzi has also called it the "costal band."

Cubital band: arising in the angle formed by the basal and marginal bands in the region of the upper cross-vein, it proceeds obliquely outward over the lower cross-vein to the hind margin of the wing. It may be quite disconnected or weakly or strongly united to the basal.

Medial band: arising towards the end of the marginal band, when fully developed crosses the last portion of the fourth vein to the wing margin. In *Trirhithrum* it is often represented by a tooth. This is the "middle band" of Bezzi.

The pattern is well-defined and generally uniform throughout the species, but is atypical in the males of *coffea* and *nigerrimum*, and in *litteratum*. The position of the upper cross-vein is somewhat variable, even within a species, but is usually on or before the middle of the discal cell, although in *nigrum* it is distinctly beyond the middle. The use of the basal hyaline streaks for separating the two groups *coffea-basale* and *leucopse-divisum* is perhaps somewhat weak, and may not be tenable if further allied species are discovered. However, in comparing the wings of *coffea* and of *leucopse*, for instance, the base of the latter is certainly much blacker-looking owing to the reduction in number and size of the streaks. It may be noted at the same time that these streaks seem very constant and characteristic of species in their detail, even when the rest of the pattern is different in the sexes. They are somewhat impracticable to use because of the difficulty in describing them. As regards the narrow, hyaline, costal edge along the marginal band, two groups of species may be noted: (a) the margin begins just below the end of the first vein, being broken at two more or less equidistant points between this and the end of the second vein, and may be linear or form three more or less shallow indentations, the outermost being the one on the end of the second vein; (b) the hyaline margin begins at about one-third the distance between the tips of the veins from the first, so that there is only one indentation, which may be quite large, before that at the end of the second vein. In both groups there is as well a similar indentation between the ends of the second and third veins, with occasionally a hyaline spot just above the tip of the third vein. In the first group belong *nigrum*, *leucopse*, *divisum*, *basale*, *nitidum*, *albonigrum*, *facetum* and *inauratifipes*; in the second *occipitale*, *brachypterum*, *coffea*, *nigerrimum*, *dimorphum*, *fraternum*, *scintillans* and *viride*.

In the present study I am indebted to and thank various workers for material and other assistance. To Miss D. Aubertin of the British Museum for data on types and the loan of determined material; to Sir Guy A. K. Marshall, Director of the Imperial Institute of Entomology; Mr. H. Hargreaves, Entomologist, Uganda; Mr. W. V. Harris, Entomologist, Tanganyika; and Mr. F. G. Overlaet, Katanga, Belgian Congo, for material. Finally Mr. W. E. Marriott at Durban who has been very helpful in rescuing Trypetids from fruit-fly bait-traps during the past few years.

The species of *Trirhithrum* recognised here may be separated in the following table:—

- 1 (2) A large species with atypical wing-pattern; there is the more usual costal hyaline indentation before the stigma and another large, completely hyaline indentation after and including the outer half of the stigma; the cubital band is recurved and widened outward fan-wise and the medial separated from the marginal.....*litteratum*, Mro.
- 2 (1) Wing pattern normal, or rarely diffuse.
- 3 (12) Scutellum flat above with base more or less broadly yellow (or white); wings usually with complete medial band.
- 4 (9) Scutellum whitish, with three black spots not visible from above on hind border; medial band complete; larger species.
- 5 (8) Two *i. or.* and 1 *mpl.*; mesopleura with whitish stripe or mostly white.
- 6 (7) Base of wing and alula dark; cubital band strong and united; medial strong; large species, 7 mm.....*validum*, Bez.
- 7 (6) Base of wing and alula hyaline; cubital band free; medial weak; smaller species, 4 mm.....*overlaeti*, sp. n.
- 8 (5) Three *i. or.* and 2 *mpl.*; no whitish stripe on pleura; wings black at base and without costal indentation before stigma.....*albonigrum* (End.)
- 9 (4) Scutellum shining black on hind third or more; smaller species.

- 10 (11) Three *i. or.* ; medial band complete and no basal streaks ; pleura black.....
nitidum (v. Röd.)
- 11 (10) Two *i. or.* ; medial band a tooth and basal streaks present ; a whitish mesopleural spot.....*albomaculatum* (v. Röd.)
- 12 (3) Scutellum not so marked, quite black or, rarely, divided into quadrate areas.
- 13 (55) Scutellum black with at most small spots on sides and a pair below, rarely a pair on top.
- 14 (52) Wings with well-defined pattern.
- 15 (20) Cubital band widely separated and no sign of medial.
- 16 (17) Two whitish hypopleural spots.....*bicinctum* (End.)
- 17 (16) No whitish hypopleural spots.
- 18 (19) Femora black in both sexes and middle tibiae feathered in male.....
facetum (End.)
- 19 (18) Legs yellow, front femora thickened and ornamented with bushy golden hairs (only male known).....*inauratiipes*, Mro.
- 20 (15) Cubital band united, occasionally narrowly separated ; medial band always present at least as a tooth.
- 21 (24) Base of wing hyaline with only small humeral band to anal (3rd basal) cell.
- 22 (23) Thorax entirely black.....*bimaculatum* (v. Röd.)
- 23 (22) A white stripe from humerus to hypopleural spot.....*viride*, sp. n.
- 24 (21) Base of wing quite black or mainly black, with a triangular or rather square hyaline indentation of greater or less extent before stigma.
- 25 (39) Pubescence on dorsum of thorax black (shining brown).
- 26 (29) Basal third of wing uniformly black with few or almost no basal hyaline streaks.
- 27 (28) Face yellow.....*homogeneousum*, Bez.
- 28 (27) Face shining black.....*gagatinum*, Bez.
- 29 (26) A hyaline indentation before stigma.
- 30 (33) Frons and face brown or black.
- 31 (32) Frons narrow ; hyaline indentation between basal and cubital bands wide, about as high as width on wing margin.....♀ *dimorphum*, sp. n.
- 32 (31) Frons wider ; hyaline indentation between basal and cubital bands narrow, about $1\frac{1}{2}$ times as high as width on wing margin.....
♂ *brachypterum*, sp. n.
- 33 (30) Frons and face not concolorous.
- 34 (38) Grey-dusted markings on abdomen.
- 35 (36) A grey-dusted band on median half of hind margin of fourth segment ; larger species.....*nigrum* (Grah.)
- 36 (37) Second, third and fourth segments each with a grey-dusted spot on dorso-central line on either side ; median band a tooth or somewhat produced to fourth vein ; smaller species.....*occipitale*, Bez.
- 37 (36) A moderate, grey-dusted dorso-central line from hind edge of second to hind edge of fourth segment ; occiput black ; smaller species.....
fraternum, sp. n.

- 38 (34) Abdomen without grey-dusted markings, entirely shining black.....
scintillans, sp. n.
- 39 (25) Pubescence on central portion of dorsum of thorax white or yellowish.
- 40 (43) Frons and face brown or black.
- 41 (42) Frons narrow ; lower parts of thorax and legs yellow ; dorsal pubescence yellowish.....♂ *dimorphum*, sp. n.
- 42 (41) Frons square ; thorax entirely, and legs mainly, black ; dorsal pubescence white.....♀ *brachypterum*, sp. n.
- 43 (40) Frons and face not concolorous.
- 44 (51) Strong costal hyaline indentation before stigma, the subcostal cell and middle two-thirds of second costal cell hyaline, the latter with perhaps a trace of a brownish spot in centre.
- 45 (48) Basal hyaline streaks numerous.
- 46 (47) Marginal band narrow and rather sinuous having two deep, broadly rounded, hyaline indentations in marginal cell.....♀ *coffea*, Bez.
- 47 (46) Marginal band broad and solid-looking, only a narrow hyaline edge in marginal cell ; frons and face of a "dark colour".....*basale*, Bez.
- 48 (45) Basal hyaline streaks much reduced, marginal band normal.
- 49 (50) Pubescence on centre of dorsum of thorax white ; pleura quite black.....
leucopse, Bez.
- 50 (49) The white pubescence more restricted and divided in median line by a narrow streak of brown pubescence ; a yellow bar along top of mesopleura
divisum, sp. n.
- 51 (44) Costal indentation before stigma weak, represented by two hyaline spots that do not cover the whole width of second costal cell, or the cell may be more extensively yellowish below spots, but the subcostal cell below is always brownish.....♀ *nigerrimum*, Bez.
- 52 (14) Wing with a diffuse pattern, not forming the usual bands ; males only.
- 53 (54) Pattern a broad, more or less ill-defined blackish band from base to apex of wing with barely traces of cubital and medial bands ; only a single hyaline spot in second costal cell.....♂ *nigerrimum*, Bez.
- 54 (53) Pattern diffuse and pale, covering whole surface ; stigma pale yellowish ; basal streaks well-developed ; an oblique hyaline area over middle portion of first posterior cell.....♂ *coffea*, Bez.
- 55 (13) Scutellum black, divided into quadrate areas by yellow lines.....
inscriptum (Grah.)

***Trirhithrum litteratum*, Mro.**

Munro 1932, p. 33, pl. iii, f. 7 (wing) (*Trirhithrum*).

The arista is shortly plumose and the upper cross-vein at about the outer third of discal cell. The species is recorded from Durban.

***Trirhithrum validum*, Bez.**

Bezzi 1920, p. 263 (*Trirhithrum*).

This species is not known to me. Only the type, a female from Entebbe, Uganda, has been recorded. It is in the British Museum.

***Trirhithrum overlaeti*, sp. n.**

A medium-sized species characterised by the white scutellum and white mesopleura. It seems very similar to *T. validum* but differs in various points ; it is much

smaller, wing length 4.2 mm., in *validum* 8.0 mm. ; the mesopleura are almost entirely white ; the base of the wing and alula are hyaline, leaving a distinct humeral band ; the medial band is less distinct and the cubital free.

Type, a male, Kapanga, Katanga, Belgian Congo, 19.iv.33, F. G. Overlaet, in author's collection.

Length of body and of wing, 4.2 mm. *Head*: length 5, height 7, width $9\frac{1}{2}$; *occiput* black on upper portion, with a semicircular yellowish patch behind vertex, sides and below yellow: *frons* about as long as wide at antennae and a quarter narrower at vertex; ocellar dot and vertical plates blackish brown, frons reddish brown on posterior three-fifths, *i.e.*, to line of anterior *s. or.* which are rather far forward, yellow anteriorly, with slight black pubescence; bristles black, 2 *i. or.*, 2 *s. or.*, *oc* very long, reaching to lunule; *ptilinum* partly exerted in specimen, so that lunule obscured; *antennae* three-fourths length of face, clear yellow, arista plumose; *face* whitish yellow, narrow, with broad, flat, median keel; cheeks brown, darker above, genae blackish purple below eyes; palpi and proboscis brown, more or less yellow-edged.

Thorax: dorsum shining black, with black pubescence, lower portions rather paler with yellowish patches, and upper three-fourths of mesopleura white with white pubescence; post-scutellum and mesophragma shining black; scutellum white, with white pubescence, an apical and a pair of lateral black spots not visible from above on hind border; bristles black, *dc.* on line of *a. sa.*, one *mpl.*, four scutellars. *Legs*: fore and middle coxae and all femora black, distal ends of femora yellowish, hind coxae and all tibiae and tarsi yellow; halteres blackish with yellow base. *Wing* normal; base and alula hyaline, a distinct humeral band united to basal in light brown axillary cell and separated by costal hyaline indentation that reaches to point of third basal cell, the second costal cell only brown at the base; basal and marginal bands normal, the latter with complete, narrow, costal hyaline edge, cubital band rather widely separated, medial a tooth faintly produced to wing margin.

Abdomen shining black, with black pubescence, a complete silvery-dusted band on posterior two-thirds of fourth segment. Venter and genitalia brown.

***Trirhithrum albonigrum* (End.).**

Enderlein 1911, p. 410, fig. A; 1920, p. 351. Bezzi 1913, p. 24 (*Ceratitis*); 1918, p. 238; 1923, p. 520; 1924a, p. 105 (*Trirhithrum*).

Originally described from Kamerun and later recorded from French Congo and Spanish Guinea. I have not seen specimens. The type is in Stettin.

***Trirhithrum nitidum* (v. Röd.).**

v. Röder 1885, p. 134 (*Ceratitis*). Bezzi 1908a, p. 139; 1908b, p. 278, 280; 1913, p. 24 (*Ceratitis*); 1918, p. 238; 1924a, p. 105; 1924b, p. 485, pl. xii, f. 31; 1928, p. 332 (*Trirhithrum*).

First described from Delagoa Bay, the species seems common on the Natal Coast. I have seen numbers of specimens collected in fruit-fly bait-traps by Marriott at Durban during the past few years. The type is probably in Berlin.

v. Röder states that the scutellum is "schwarz gerandet" without further comment. In my specimens there is always a pair of yellow spots below the apex, and these spots are often extended a good way upwards but not far enough to divide the black.

***Trirhithrum albomaculatum* (v. Röd.).**

v. Röder 1885, p. 136. Bezzi 1908a, p. 129; 1908b, p. 278, 280 (*Ceratitis*); 1918, p. 241; 1924a, p. 105; 1924b, p. 485, pl. xii, f. 29. Munro 1925, p. 51 (*Trirhithrum*).

Originally described from Delagoa Bay, it is widely spread but not very common in the south-eastern parts of South Africa. I have seen specimens from Grahamstown, East London, Durban (taken in bait-traps) and Maritzburg (reared, Marriott). The larvae have been found only in the fruits of the Kei apple (*Dovialis caffra*) but never in numbers.

v. Röder states that the arista is bare, but it is actually minutely pubescent. The type is probably in Berlin.

***Trirhithrum bicinctum* (End.).**

Enderlein 1920, p. 349, ♀ (*Ceratitis*). Bezzi 1924a, p. 106 (*Trirhithrum*).

Only recorded from the Gold Coast; Bezzi redscribes the species. I have not seen specimens.

***Trirhithrum facetum* (End.).**

Enderlein 1920, p. 349, ♀ (*Ceratitis*). Bezzi 1924a, p. 106. Munro 1933, p. 6, ♂ (*Trirhithrum*).

The type, a female, is from West Africa. I described the male from the Belgian Congo. The species is a *Trirhithrum* although the middle tibiae are feathered in the male.

***Trirhithrum inauratipes*, Mro.**

Munro 1933, p. 7 (*Trirhithrum*).

A very distinct species described from a single male from the Belgian Congo.

***Trirhithrum bimaculatum* (v. Röd.).**

v. Röder 1885, p. 136. Bezzi 1908a, p. 139; 1908b, p. 280 (*Ceratitis*); 1918, p. 239; 1924a, p. 105; 1924b, p. 486 (*Trirhithrum*). Enderlein 1930, p. 347 (*Ceratitis*).

This was originally described from Delagoa Bay. Enderlein records it from Spanish Guinea, and as v. Röder's descriptions are good, there should be little doubt that Enderlein's determination is correct. The appearance of the base of the wing seems to be quite distinctive. The type is probably in Berlin. I have not seen specimens.

***Trirhithrum viride*, sp. n.**

This species is apparently allied to *bimaculatum*, v. Röd., as the wing-pattern seems to be very similar, particularly the hyaline base and humeral band; but while the thorax in *bimaculatum* is entirely black, in this species there is a white stripe from and including the white humerus across the top of the mesopleura and wing base to the white hypopleural spot. In some ways too this species seems allied to certain species of *Perilampus*.

Type, a female, Durban, 1-11.ix.33, taken in bait-trap, W. E. Marriott, in author's collection.

Length of body, 3.8 mm., of wing, 3.4 mm. *Head*, length 1, height $1\frac{1}{2}$, width 2; *occiput* flat, black above, with semicircular yellow area behind vertex, yellow below, bristles black; *frons* greenish yellow, vertical plates white, orbits pale whitish, round brown ocellar dot a whitish edge that extends forward narrowly on the median line to front edge of vertical plates, where there is a slight, irregular, transverse brown bar; *frons* nearly twice as long as wide; slight blackish pubescence; bristles black, 2 i. or., 2 s. or., *oc* moderate, reaching to middle of *frons*; *antennae* yellowish-brown, three-quarters length of face, arista rather sparsely plumose, plumosity about three-fifths

width of third antennal joint ; *face* flat, white, moderately brown below antennae, cheeks linear, yellow, genae narrow, less than half width of third antennal joint, yellow ; palpi and proboscis yellow.

Thorax brownish black, blacker on dorsum, rather long, white pubescence, brown above wing bases, and slight grey dust ; humeri white with a small black dot, a broad white stripe along sides across wing base to single white hypopleural spot ; hind portion of mesopleura yellowish brown ; pubescence on pleura whitish, on sterna black ; bristles normal, black, one *mpl.* *Scutellum* with a suspicion of flattening on the sides, reddish black, with black pubescence and on each side a pair of triangular white spots one above the other, their points touching ; four bristles (apicals abraded in specimen). *Halteres* yellow. *Legs* : front coxae, all femora and proximal halves of four hind tibiae black, otherwise yellow. *Wing* normal, base (including alula and axillary cell hyaline) with a short irregular humeral band to third basal cell, the basal hyaline streaks large and well-developed ; basal band normal ; marginal with incomplete hyaline edge, stigma dark with yellow spot at end ; cubital band strongly united, medial a tooth.

Abdomen shining black with black pubescence ; second segment entirely grey-dusted and with whitish pubescence, third and fourth segments with a broadly triangular grey patch on middle half, but on each this is broken on the middle line ; sixth segment slightly grey-dusted. Base of ovipositor short, not as long as fourth and fifth segments together ; shining brown with black pubescence ; flattened in specimen but probably short legging-shaped in life ; second joint yellow.

***Trirhithrum* *homogeneum*, Bez.**

Bezzi 1924a, p. 105 (*Trirhithrum*).

The species is not fully described by Bezzi. Through the kindness of Dr. Z. Szilády of the Hungarian National Museum I have been able to examine the type. It is only labelled "Deutsch O. Afrika," and is, unfortunately, in very poor condition, so much so that little more can be said than that it is entirely black, the vestiture being all abraded. The basal two-fifths of the wing is quite black, with only two or three slight hyaline streaks ; the cubital band is united to the basal and there is a narrow medial reaching the fourth vein.

I have two specimens sent by Mr. H. Hargreaves from Uganda (Nanandala, 11.xii.1924, and Entebbe, 28.iv.1909, No. 478) that may be regarded as this species, but a direct comparison with the type (which is no longer in my possession) would be necessary to make quite sure. In these, a male and a female, the face is yellow, the frons orange and slightly wider than long, the medial band on the wing is a tooth, and there are no grey-dusted marks on the abdomen. The base of the ovipositor is short, broad, conical, a little shorter than the pre-abdomen.

***Trirhithrum* *gagatinum*, Bez.**

Bezzi 1918, p. 238, ♀ ; 1924a, p. 106 (*Trirhithrum*).

Only the type is known, a female from the Gold Coast, in the British Museum. It seems to be very like *T. homogeneum* but differs in the shining black face.

***Trirhithrum* *brachypterum*, sp. n.**

Apart from the differences given in the table, this species seems to differ from all others in the subgenus by the much broader wings and the much smaller angle between the outer edge of the basal and the inner edge of the cubital bands.

Type, male, Entebbe, Uganda, 8.xi.1909, and female, 26.xi.1909. In British Museum, both specimens rather damaged.

♂. Body length uncertain as head is missing, but probably same as wing length, 3.2 mm. *Thorax* black with no yellow marks at all; pubescence, bristles and halteres black; legs black, outer halves of tibiae yellowish, tarsi yellow. *Wing* wider than usual, width about half length, extreme base and alula black; like that of female (fig. 1) but the outer indentation at the end of the submarginal cell is also rather square and there is a moderate, oval, hyaline spot at the inner end of the third posterior cell. *Abdomen* short, shining black with black pubescence; there seems to be a trace of grey dust on hind margin of fourth segment, but it is difficult to say definitely owing to the condition of the specimen.

♀. With but little doubt this female is that of the male just described in spite of the difference in the colour of the dorsal thoracic pubescence. There are slight differences in the wing pattern which are probably sexual, but the main features and the shape of the wings are almost identical. Both are from the same locality and have been given the same number by the collector but unfortunately his data are not available.

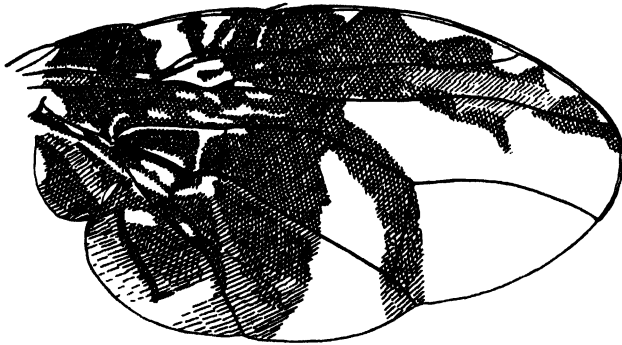


Fig. 1. *Trirhithrum brachypterum*, sp. n., wing of ♀.

The specimen is rather damaged and as one wing was badly broken it was removed and mounted for pinning below the insect. Length of body and of wing, 3.7 mm. *Head*: length 2, height 3, width 4; entirely brown, including appendages; the occiput seems to have some thick grey dust, but this is probably dirt; *frons* only slightly longer than wide, with slight black pubescence, bristles black, 2 i. or., 2 s. or., oc moderate, reaching to middle of frons; *lunule* inconspicuous; *antennae* about as long as face, both aristae broken off; *face* flat, cheeks linear, genae narrow. *Thorax*: dorsum shining black, with white pubescence, black on sides; pleura and lower parts duller, blackish brown. *Scutellum* rounded, shining black with a pair of pale yellowish spots on top. *Halteres* black. *Legs* black, anterior tibiae and all tarsi yellow. *Wing* (fig. 1): it may be noted that the basal band reaches well towards the middle of the wing; there is a hyaline spot at tip of stigma; the hyaline costal edge to the marginal band is incomplete but the indentations are strong, that on the end of the second vein being rather square; there is a pale yellowish area towards the end of the marginal band above the short medial band. *Abdomen* shining blackish brown, pubescence black, slight grey dust on middle portion of hind margin of second segment and a pair of pale grey-dusted spots on dorso-central line on third and fourth segments. Base of ovipositor short, about three-fourths length of fourth and fifth segments together: venter blackish.

***Trirhithrum nigrum* (Grah.).**

Graham 1910, p. 162, pl. xii, f. 1, ♀. Speiser 1911, p. 259. Bezzi 1912, p. 26 (*Ceratitis*); 1918, p. 238; 1924a, p. 106 (*Trirhithrum*); Hendel 1912, p. 15. Enderlein 1920, p. 348. Lamborn 1914, p. 206 (*Ceratitis*).

Syn. *Ceratitis obscura*, End., 1911, p. 410.

The species seems common across Central Africa. It has been recorded from Nigeria, Kamerun and Belgian Congo. I have compared a specimen from Uganda (Busongoro Toro, xii, 1927, G. D. H. Carpenter) and a series from Belgian Congo (Kapanga, Katanga, xii, 1932, F. G. Overlaet) with a pair from Southern Nigeria sent me on loan from the British Museum and found they are the same.

This is the genotype of the subgenus. The arista is long plumose; the face yellow on the lower two-thirds, the upper portion brown, the brown forming a band that includes the lower third of the frons.

Hendel (1912) gives *Ceratitis obscura*, End., as a synonym, and this seems correct, so far as may be judged without seeing Enderlein's type in Stettin.

Lamborn records it as numerous in cacao fields in Southern Nigeria, but he states that an investigation into its relation to the cacao pods was not possible at that time.

***Trirhithrum occipitale*, Bez.**

Bezzi 1918, p. 239, pl. v, f. 7, ♀; 1924a, p. 106; 1924b, p. 486, pl. xii, f. 30. Munro 1925, p. 51 (*Trirhithrum*).

Syn. *Ceratitis ochriceps*, End., 1920, p. 347.

The type, a female from Nyasaland, is in the British Museum. The species is common on the south-east coast of South Africa, where the larvae infest the fruits of wild grapes (*Cissus cirrhosa* at East London, Munro, and *Cissus hypoleuca* at Durban, Marriott). It has also been taken in numbers in bait-traps at Durban (Marriott) and a single specimen in a bait-trap at Rosslyn, near Pretoria (J. D. Sim).

Grey-dusted spots occur on the abdomen on the second, third and fourth segments on the dorso-central line, but sometimes appear to be only on the fourth unless searched for carefully. The wing-pattern is the same in the sexes. The medial band in South African specimens is only a tooth, but is often continued faintly to the fourth vein.

Bezzi suggested that *Ceratitis ochriceps*, End., was a synonym. This is probably the case owing to the colour of the frons, but in *ochriceps* there appears to be a moderately strong medial band. An examination of the type in Stettin would be needed for confirmation.

The specimens reared from coffee berries in Natal and recorded by me as *T. occipitale* (1929, p. 11) are not this species, but *T. nigerrimum*, Bez.

***Trirhithrum fraternum*, sp. n.**

Allied to *T. occipitale*, Bez., but differing in the black occiput and pair of entire, grey-dusted stripes on the abdomen on the dorso-central line. *T. coffeae* has similar stripes but differs in details of the wing-pattern, colour of dorsal thoracic pubescence, etc.

Type, male, Njala, Sierra Leone, 4.viii.25, E. Hargreaves; type, female, Entebbe, Uganda, 4.iii.09, H. Hargreaves. In British Museum.

♂. Length of body, 3.2 mm., of wing 3.4 mm. Head, length $4\frac{1}{2}$, height 7, width 9; occiput flat, black; frons slightly longer than wide, and a little wider than an eye, more or less mottled yellow and brown, ocellar dot and streaks on inner sides of yellowish vertical plates, black, a light brownish band across middle of frons extending backwards on sides to surround vertical plates, leaving a yellowish spot before ocelli, anterior part of frons yellowish, with a blackish spot on each side at bases of antennae connected by a narrow black line along edge of inconspicuous lunule; slight black pubescence; bristles black, oc moderate, 2 s. or., 2 i. or. Antennae broken off in specimen. Face flat, and, with cheeks, yellow, latter brownish above, genae becoming brown below eyes; palpi yellow, proboscis blackish.

Thorax shining black, with black pubescence, only a yellow spot on each side of scutellum and a pair below its apex ; bristles black, one *mpl.*, four scutellars. *Legs* with femora black ; tibiae and tarsi yellow, only proximal ends of tibiae blackened ; halteres black. *Wing* (fig. 2) : as the extreme base is more hyaline than usual and there is a clear costal hyaline indentation before the stigma, the upper part of the humeral band is better defined ; below it is confluent with the basal and the hyaline streaks are reduced. The infuscation of the apex of the hyaline indentation between the marginal and cubital bands may be noted ; the upper cross-vein is at about the inner fourth of the discal cell.

Abdomen shining black, with black bristles and pubescence and a pair of grey-dusted streaks from hind margin of second to hind margin of fourth segments ; genitalia black.

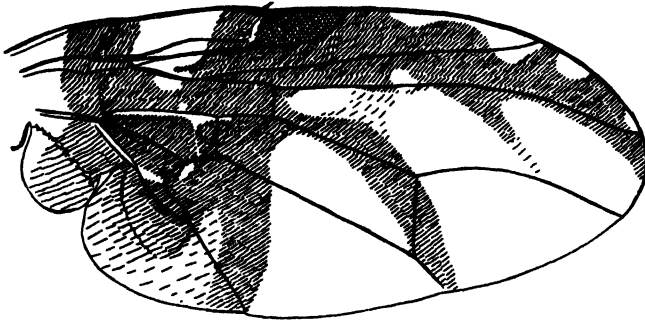


Fig. 2. *Trirhithrum fraternum*, sp. n., wing of ♂.

♀. After some hesitation, it seems certain that the female described here is that of the male just recorded in spite of the fact that the localities are so far apart. The head is unfortunately missing ; the wing length is 3.9 mm., so the total length would be about the same. Further the specimen agrees closely with the male. The legs are black, only the tarsi yellow and distal ends of tibiae yellowish. The main features of the wing pattern are as in the male—the square hyaline indentation before the stigma, the reduced basal hyaline streaks and the appearance of the marginal band along the costa. In contrast, the cubital band is separated and there is no infuscation between the marginal and cubital bands ; the medial band is a blunt tooth and there is no hyaline spot above the tip of the third vein. The base of the ovipositor is short, about three-fourths the length of the fourth and fifth segments together ; it is concolorous with the abdomen and flattened in the specimen.

***Trirhithrum scintillans*, sp. n.**

An entirely shining black species with only the face white and tibiae and tarsi yellow. Allied to *occipitale* but differs in blackish frons and absence of grey markings on the abdomen.

Type ♂ and ♀, Kapanga, Katanga, Belgian Congo, i.1932, F. G. Overlaet ; in author's collection.

Length of body, male, 3.2 mm., female 4.4 mm. ; of wing, male, 3.7 mm., female 4.4 mm. *Head*, length 3, height 5, width 6 ; *occiput* flat, black ; *frons* a little longer than wide, as wide as an eye in female, about one-fifth narrower in male, shining black behind and on vertical plates, yellowish between latter and anteriorly, but blacker on each side of antennae ; slight black pubescence, bristles black, *oc.* strong, 2 *i. or.*, 2 *s. or.* *Lunule* inconspicuous. *Antennae* blackish brown, half length of face, arista long plumose ; *face* flat, yellow, brown below antennae, epistome very slightly projecting ; cheeks narrow, whitish, genae brown below eyes ; palpi yellowish ; proboscis short, brown.

Thorax shining black, only brownish on hind parts of pleura and sterna ; pubescence black ; bristles black, normal, one *mpl.* *Scutellum* as thorax, with no yellow spots, four bristles. *Legs* black, only fore tibiae, distal ends of other tibiae and all tarsi yellow. Wing with normal venation and well-marked pattern in both sexes ; basal two-fifths black, with a small costal hyaline indentation before stigma, basal hyaline streaks reduced ; marginal band moderately indented along costa ; medial band a tooth ; cubital band strong, broadly united. *Abdomen* shining black, with black pubescence and bristles and no grey markings. Base of ovipositor short, as long as segments 5 and 6 together, rather broad and flattened, shining black and with black pubescence ; male genitalia black.

***Trirhithrum dimorphum*, sp. n.**

A small black species with only the tarsi yellow in female, but legs and most of lower portions of thorax yellow in male ; in both sexes frons and face blackish ; in male the tip of the sixth vein bent inwards and just outside and touching it a large, round, deep black spot.

Type ♂ and ♀, Gendema, Sierra Leone, 11.ii.25, E. Hargreaves : in British Museum.

Length of body, male, 3.2 mm., female, 3.4 mm. ; of wing, both sexes, 3.2 mm. *Head*, about twice as wide as long, height a little less than width (somewhat narrower in male than in female) ; *occiput* flat, dull black, yellow below in male only ; *frons*

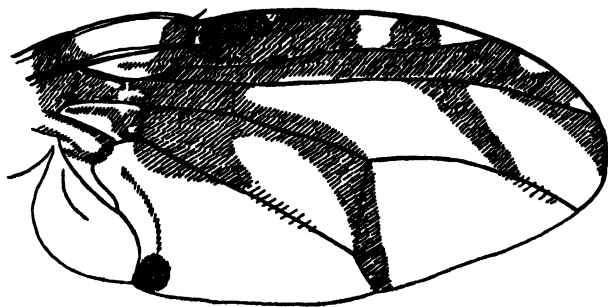


Fig. 3. *Trirhithrum dimorphum*, sp. n., wing of ♂.

narrow, nearly one-third longer than wide, about $\frac{1}{4}$ narrower than an eye, rather narrower in male, dull black, or deep blackish brown, ocellar dot black, some slight black pubescence ; bristles black, *oc.* long, 2 *s. or.*, 2 *i. or.* ; *lunule* inconspicuous ; *antennae* blackish brown, $\frac{3}{4}$ length of face, there is a strong bristle-like seta on the second joint in both sexes, arista long plumose ; *face* flat, rather shining black, epistome flat ; cheeks linear, genae wider becoming yellowish below eyes ; palpi and proboscis blackish yellow, eyes large.

Thorax, male, dorsum black with very faint grey dust and rather long, pale, yellowish pubescence, humeri yellow above and below, black in middle, a small yellow notopleural dot ; pleura yellowish, but upper portions of mesopleura blackish, grading to yellowish in front and below and a pale yellow, rather broad stripe along top of mesopleura ; propleura blackened ; rather long, pale, yellowish pubescence on pleura ; sterna yellow ; post-scutellum and mesophragma black ; scutellum black with yellow spot on each side. *Thorax*, female, quite black, only slightly paler on hind parts of pleura, and a yellow spot on each side of scutellum ; bristles black, one *mpl.*, four scutellars. *Legs*, male, yellow, female, black with tarsi yellow. *Wing*, male (fig. 3) ; female, much as in male ; the costal hyaline spot in middle of marginal cell not so deep and no hyaline spots at tip of stigma and of sub-marginal cell ; the end of the sixth vein normal, and without a black spot before it ; the basal band goes normally to wing margin and end of sixth vein and there is no prolongation along fifth

vein. *Abdomen* shining black, with black pubescence; male genitalia, black; base of ovipositor short, about three-fourths length of fourth and fifth segments together, broad, black, with black pubescence.

***Trirhithrum coffeae*, Bez.**

Bezzi 1918, p. 241, pl. v, f. 9 (*Trirhithrum*).

Syn. *Trirhithrum inscriptum*, Bez. (nec. Grah.) 1924a, p. 106, 108.

The identity of this species was much confused by Bezzi. He described it as a variety of *nigerrimum*, but it is quite distinct, as it is also from *inscriptum*, Grah. The confusion in this species and also in *nigerrimum* is due to the fact that Bezzi failed to realise that the diffuse appearance of the wing-pattern was normal in the males, and not due to a teneral condition. In teneral females the pattern is merely faint, remaining well-defined.

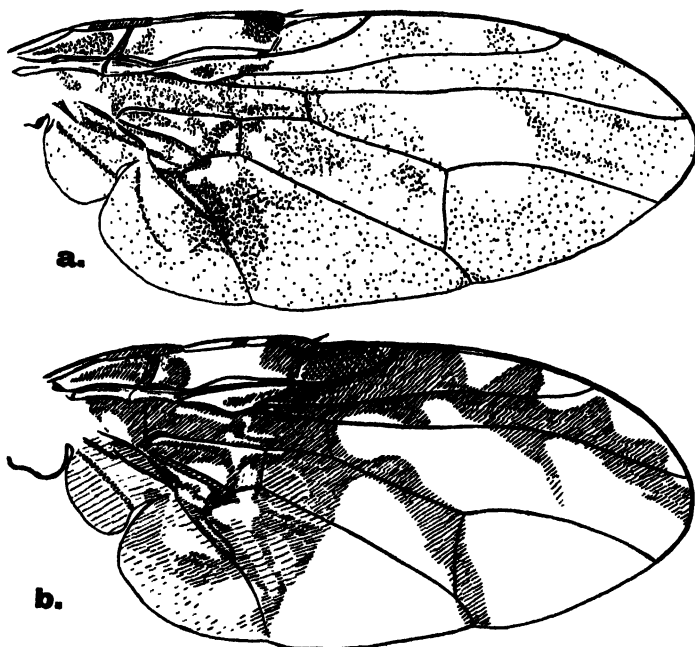


Fig. 4. *Trirhithrum coffeae*, Bez.; wing of: a, ♂; b, ♀.

Each sex of *coffeae* may be recognised by its wing-pattern; the peculiar, diffuse, very pale appearance in the male (fig. 4, a) and the almost sinuous marginal band in the female (fig. 4, b). It may also be noted that there is always some trace of a narrow yellow notopleural stripe, usually stronger in the male in which it may even extend to the humerus, which is then yellow-margined. Such a yellow streak is absent in *nigerrimum*. The tibiae are black or mainly black. The yellow spots below the apex of the scutellum are generally larger and more conspicuous. In the female type the hyaline division between the marginal and cubital bands ends squarely on the upper cross-vein both according to the description and from a sketch kindly sent to me by Miss Aubertin, but more usually it ends more roundly a little before the cross-vein. The cubital band in the female is united, but out of twenty-five specimens from Uganda, two had it definitely, but not widely, separated from the basal.

Of *coffeae* I have seen the following material:—

Three females and a male from the British Museum: thirty-three from various localities in Uganda from Mr. H. Hargreaves, and six from Tanganyika received from

Mr. W. V. Harris. Both the Uganda and Tanganyika series included specimens reared from larvae in coffee berries.

***Trirhithrum basale*, Bez.**

Bezzi 1924a, p. 107 (*Trirhithrum*).

The types, male and female, are in the British Museum. From a drawing of the wing-pattern of the female type kindly sent to me by Miss Aubertin, the marginal band is solid looking, filling the whole of the marginal and submarginal cells; with only a very narrow hyaline edge along the costa in the former and a wider edge at the end of the latter; the medial band is a very short tooth, and the cubital disconnected, apparently somewhat widely; the basal hyaline streaks are reduced and generally different from what is found in both sexes of *coffaeae*. In the wing-pattern, too, this species differs from *dimorphum*. This point is mentioned because from the description, *basale* would seem to have a similar narrow, brown ("of a dark colour" according to Bezzi) frons and face.

***Trirhithrum leucopse*, Bez.**

Bezzi 1918, p. 240; 1924a, p. 106, 108 (*Trirhithrum*).

The male type is in the British Museum, the female apparently in the Bezzi collection in Milan.

The wing-pattern is not dimorphic and the species may be distinguished by the large hyaline indentation before the stigma (almost the whole of the second costal cell is hyaline as well as the portion of the sub-costal cell below it) and the much reduced basal hyaline streaks. The hyaline edge along the marginal band is narrow but widens to fill the end of the sub-marginal cell; the cubital band is strongly united.

The face is yellow, only narrowly brown below the antennae; the pair of yellow spots below the apex of the scutellum may be present or absent; there is no sign of a grey-dusted pattern on the dorsum of the thorax.

Of this species I have examined two specimens kindly sent on loan from the British Museum, and I have a pair from Nyasaland received from Sir Guy Marshall.

***Trirhithrum divisum*, sp. n.**

Close to *leucopse*, Bez., but differs in having a moderately strong yellow stripe along the top of the mesopleura and on the dorsum of thorax restricted white pubescence which is divided by a streak of brown pubescence on the median line.

Type, a female, Durban, 23-30.vi.1933, W. E. Marriott, taken in pollard bait-traps, in author's collection.

Length of body, 4.3 mm., of wing 3.7 mm. *Head*, length 2, height 3, width 4; *occiput* flat, black with a narrow yellowish orbital margin that widens considerably below and a pale yellow spot behind vertex; *frons* about one-fourth narrower than long, flat, slight black pubescence, black behind upper *s. or.*, whitish yellow otherwise, but blackened across central portion; bristles black, *oc.* moderate, 2♂. *or.*, 2 *i. or.*; *lunule* inconspicuous; *antennae* blackish yellow, $\frac{2}{3}$ length of face, arista rather sparsely plumose; face flat, white on lower two-thirds, brown above the brown forming a band that includes the bases of the antennae and reaches from orbit to orbit; cheeks narrow, yellow, brownish above, genae brown below eyes; palpi blackish yellow; proboscis dirty white.

Thorax, dorsum shining black, there is an area of grey dust from suture between dorso-central lines to *dc.* bristles where it widens to hind margin, in front it widens also along hind edge of suture, on this area the pubescence is white, otherwise black and a narrow streak of black dividing the white on the median line; humeri yellow on inner side; pleura shining black with black pubescence, a strong yellow streak along top of

mesopleura ; wing base and mesopleural suture whitish ; hind parts of pleura and of sterna with yellowish tinge ; bristles normal, black, one *mpl.* ; legs (front pair missing) black, except outer half of tibiae and all tarsi yellow ; *halteres* black ; *wing*, a well-defined hyaline indentation before stigma, basal streaks reduced, three moderate indentations along marginal band, cubital band broadly united, medial a tooth. *Scutellum* shining black, with black pubescence and four bristles ; post-scutellum and mesophragma shining black. *Abdomen* shining black with black pubescence and with a grey-dusted band on middle third of hind two-fifths of fourth segment, the band disconnected on the middle line, but there is a narrow connecting bar over this spot ; sternites shining black, membranes dull blackish, becoming whitish between sixth segment and base of ovipositor where there is a central and a pair of smaller lateral black spots ; base of ovipositor somewhat flattened, short conical, about as long as segments four and five together, shining black, but somewhat yellowish below.

***Trirhithrum nigerrimum*, Bez.**

Bezzi 1913, p. 26, f. 3 ; 1914, p. 303 (*Ceratitis*) ; 1918, p. 240 ; 1924a, p. 108 (*Trirhithrum*). Silvestri 1914, p. 72. Pierce 1917, p. 116. Enderlein 1920, p. 348, ♀ (*Ceratitis*).

Syn. *Ceratitis patagiata*, End. 1920, p. 350, ♂. *Trirhithrum occipitale*, Mro. 1929, p. 11.

This was described inadequately as a variety of *T. nigrum* (Grah.), a species to which it is not closely allied. When Bezzi recorded *nigerrimum* in 1918 he described *leucopse* and *coffea* as varieties of it. It is here that it is evident he was not clear as

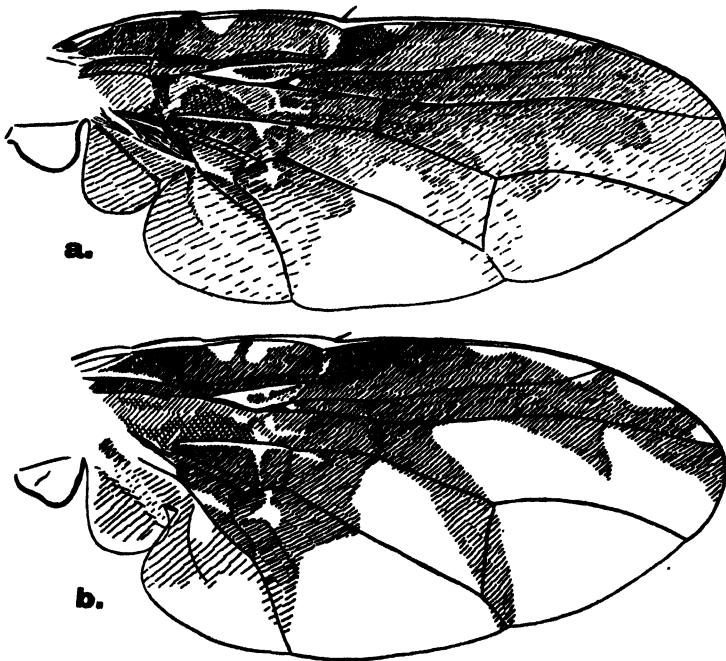


Fig. 5. *Trirhithrum nigerrimum*, Bez., wing of : a, ♂ ; b, ♀.

to these species. Under *nigerrimum* he states that none of the specimens he saw were in good condition, that the species seemed variable, variation being possibly due to differences in host-plants, and that related forms might be present. Further, under

coffea he says "It is curious that Prof. Silvestri at the same locality (Aburi) in January 1913 bred from coffee fruits the form above recorded as *nigerrimum*, which differs from the present one in the colour of the face and wing pattern. These variations may be only individual, or they may depend on the breeding conditions, or even on the state of preservation of the specimens." The explanation is that the wing-pattern is dimorphic, and apart from this neither species is particularly variable. In the male the pattern is a broad band that includes most of the fore part of the wing (fig. 5, *a*); the basal streaks are reduced and the hyaline indentation before the stigma is represented by a single small hyaline spot on the second costal cell; in the female (fig. 5, *b*) there are two moderate hyaline spots that do not reach across the second costal cell; the portion of the subcostal cell below is always brownish, and this serves to distinguish the female from *occipitale* and *coffea*, to the former of which it is otherwise very similar, especially if the dorsal pubescence on the thorax is rubbed. The stigma is deep black in both sexes. There is no sign of a yellowish notopleural stripe. The spots below the apex of the scutellum are small and may be absent. The tibiae and tarsi are yellowish but may be blackened, more so in the hind tibiae of the female. If the thorax of the male is viewed obliquely there may be seen a faint grey-dusted pattern. In both sexes the frons is distinctly silvery when seen obliquely from in front.

As is the case with *coffea*, it is not possible to connect the male with Bezzi's description, and it is not surprising that Enderlein described the male as a new species. The first male I obtained I determined without hesitation as *Ceratitis patagiata*, End.

I cannot make anything of the name *dispertita*. It is used by Enderlein in his "description" of *Ceratitis festiva* and I can also not discover why Bezzi regarded it as a synonym of *nigerrimum*. It would appear to be a *nomen nudum*. The point is discussed again below.

The identification of the specimens recorded by me as *occipitale* was made before I was acquainted with *nigerrimum*, and it is based, too, on the assumption that in teneral specimens the pattern would tend to become diffuse (as actually seems to happen in species of *Dacus*).

I have examined the following material:—

A male, Bulucheke, Uganda, 3.i.32, G. L. R. Hancock; 4 females and a male from Tanganyika; 2 males and 2 females from Gold Coast; a male, Sandoa, Katanga, Belgian Congo, ii.1932, F. G. Overlaet; 2 males kindly sent to me by Prof. Silvestri from the series reared by him in West Africa in 1913; a pair from Tanganyika, W. V. Harris; 5 males and 8 females collected in bait-traps at Durban, 1930–1933, W. E. Marriott; lastly the pair reared by Fuller from coffee berries in Natal, which I recorded as *occipitale*.

Biology.—The species seems to be a common pest of coffee berries in East and West Africa. Silvestri reared it from fruits of a species of *Eugenia*. The two Gold Coast specimens mentioned above were from the British Museum, and one male is labelled "Accra, 1920, from fruit of *Erythroxylon coca*, Mrs. W. H. Patterson."

***Trirhithrum inscriptum* (Grah.).**

Graham 1910, p. 164, ♂. Bezzi 1912, pp. 6, 24 (*Ceratitis*); 1918, p. 235 (*Pardalaspis*).

This is a distinct species, of which only the male is known.* The fact, clearly stated by Graham, that the black scutellum is divided into quadrate areas by yellow lines (as in many species of *Pardalaspis*) seems to have been quite overlooked. Besides, the wing-pattern is well-defined in the male and would therefore undoubtedly

*Since writing this Miss Aubertin informs me there are two females in the British Museum, both collected by Graham at the same place and time as the male type. They run to *inscriptum* in the tables given here.

be so in the unknown female. Hence, *coffaeae* can have nothing to do with it. The true *T. inscriptum* is actually omitted from Bezzi's tables, the species given by him (in 1924) under this name being *T. coffaeae*.

***Ceratitis festiva* (End.).**

Enderlein 1930, p. 349 (*Ceratitis*).

Although such data as are available would point to this being a *Trirhithrum*, I am not able to accept it as a described species. It is compared with *C. dispersita*, which is, as far as I can discover, a *nomen nudum*. Under *Trirhithrum nigerrimum*, Bezzi (1924a, p. 348), says "The present species was redescribed by Enderlein (1920, p. 348) and previously named *Ceratitis dispersita* (p. 349)." Just what Bezzi meant by "previously" is difficult to say, as there does not appear to be an earlier description and Bezzi actually mentions a later reference. Perhaps he intended "incorrectly" as he accepted *dispersita* as a synonym of *nigerrimum*. However, for whatever reason the name *dispersita* got into Enderlein's text, I can see no reason why it should be taken to refer to *nigerrimum*, even though a re-description of the latter is given just before. Hence, the description for *Ceratitis festiva* cannot be accepted.

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Note.—The only one of the above publications not seen by me is that of Speiser, 1911.

FURTHER STUDIES UPON CHEMICAL FACTORS AFFECTING THE BREEDING OF *ANOPHELES* IN TRINIDAD.

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During the last decade, entomologists have made progress in understanding the environment in which certain insects live ; in particular, we begin to understand the effect of certain physical and chemical factors, which make up a part of the environment. With this gain in knowledge, it is sometimes possible to forecast outbreaks of insects and of diseases conveyed by them, and one can sometimes say that a particular alteration of the environment will result in loss or gain. But so far as mosquitos are concerned, one must admit that though much work has been devoted to the analytical study of the water in which the early stages are passed, the results are disappointing. A consideration of the published work suggests several reasons for this. Investigation into the ecology of the mosquito has had a vogue, and much of it has been done by workers who were isolated and whose knowledge of chemical technique and freshwater biology was limited. Apart from that, the inherent difficulties are great, for the worker must hunt for the limiting chemical and physical factors among a host of others which are doubtless unimportant, and there are few clues to indicate which of the chemical constituents of the water affects the mosquito. The data are therefore voluminous and it is difficult to reduce them to order and present them so that they can be readily understood.

I have here endeavoured to make fuller use of some facts collected by my former colleague, Dr. Mary Beattie (1932) ; in this I have been greatly helped by my statistical colleague, Dr. J. O. Irwin. It will be remembered that Dr. Beattie spent two years in Trinidad, British West Indies, investigating the physical and chemical factors which might affect mosquito breeding, confining her attention to *Anopheles tarsimaculatus*. At regular fortnightly intervals, she carried out a rather full programme of analysis, determining nine factors and measuring the population of *Anopheles* by the number of larvae obtained in a dip. In all, she collected about 300 readings of each factor. During the first year she investigated water of a general character—principally six ponds ; she concluded that there were no great seasonal changes in the chemical factors, most of which appeared to have no relation to the number of larvae in the water, though the ammonia nitrogen seemed to be a limiting factor. In the second year she studied water in irrigation canals and rice-fields, and found additional evidence for thinking that ammonia nitrogen was important.

This is clearly shown in Table I, which is based on the original data which have never been published in full ; it includes the analyses of ponds in the first year and of rice-fields and canals in the second. The table shows the number of occasions on which a certain number of larvae were found associated with a particular concentration of ammonia nitrogen. It will be seen that larvae were rarely found when the ammonia nitrogen figure was above 0.03 parts per 100,000 ; moreover, when larvae were found with higher concentrations, their numbers were low. If one passes to the lower figures of ammonia nitrogen, there is a steady increase in the number of occasions on which larvae were found and in their actual numbers when present. It is clearly shown in the last column that, as the concentration of ammonia nitrogen rises, the number of larvae falls. The table also shows that the correlation is not very close, for it is impossible to say that a particular number of larvae will be found with a particular concentration of the chemical factor.

A statistical examination of the numbers has been undertaken. The value of the correlation coefficient (r) is $-.3372$ and that of the correlation ratio of larval number on ammonia nitrogen (η) $.3983$. Both figures are significant, and the difference between them is also significant by the z test. These tests support the conclusion that a considerable correlation exists, but it appears that the effect of ammonia nitrogen only accounts for a little more than 12 per cent.* of the variation in the number of larvae. Moreover, as η significantly exceeds r , the curve of regression is not linear.

In her second year's work, Beattie discovered that larvae were more numerous in the irrigation canals than in the rice-fields; moreover, there were certain rice-fields in which larvae were generally present and others from which they were nearly always absent. This also appeared to be closely related to ammonia nitrogen. In examining her data, one finds that the concentration of ammonia nitrogen in the canals was always below 0.04 parts per 100,000; the range of values is so slight that no correlation is observed or could be expected between them and the number of larvae. But in the fields, concentrations ranging from under 0.02 to 0.13 were observed (82 determinations). The distribution of larvae at different values of ammonia nitrogen resembles that shown in Table I, and the figures need not be reproduced. The correlation coefficient is $-.4255$ and the correlation ratio $.5016$. The figures are significant,

TABLE I.

Giving values of ammonia nitrogen, as parts per 100,000, and number of occasions on which larvae of *Anopheles tarsimaculatus* were found in association.

Ammonia nitrogen	Number of larvae							Total occasions	Mean larvae
	nil	1-5	6-10	11-15	16-20	21-25	26 & up		
.10-.15	9							9	0.0
.08-.09	8	1						9	0.3
.06-.07	11	2						13	0.46
.04-.05	27	1						28	0.11
.02-.03	36	32	7	3	1			79	2.65
under .02	24	73	55	18	13	1	9	193	7.85
Total ...	115	109	62	21	14	1	9	331	

as is the difference between them. It will be seen that if one takes the data from rice-fields alone, the correlation is considerably higher than that found by considering rice-fields, canals and ponds together, as was done in Table I. The reason may be that in the rice-fields conditions were more uniform than in the larger and rather heterogeneous group of waters. But even here, with the higher correlation, only a little more than 18 per cent. of the variation in the number of larvae is attributable to the ammonia nitrogen.

Inasmuch as the ammonia nitrogen figures are high in some rice-fields but not all, we may suppose that the ammonia is not due to the cultivation of rice itself, but to some extraneous factor. Beattie's view that it is due to surface drainage from homesteads is doubtless correct.

One would expect to find some correlation between the figures for organic nitrogen and number of larvae, for though the techniques for estimating ammonia nitrogen

* The square of the correlation coefficient giving an approximate measure of the amount of variation in one factor which can be accounted for by the other, understating it somewhat if the regression is not linear.

and organic nitrogen are dissimilar, both give a measure of the organic contamination of the water. The results obtained during the whole period of work are presented in Table II. It seems that organic nitrogen is correlated with the presence of larvae but that its influence is not so great as that of ammonia nitrogen. One observes that larvae may be present at all the concentrations of organic nitrogen, but they are more frequently present and also more numerous at moderate and lower figures. The means given in the last column show this clearly. The larvae are scarce at the three highest concentrations of organic nitrogen, but at all the lower concentrations there is no consistent rise or fall in the mean number of larvae. Examining the figures statistically, the correlation coefficient is found to be -0.1400 and the correlation ratio $.2774$. Both are significant and the difference between them is also significant.

Beattie has already stated her conclusion that the following factors showed no correlation with numbers of larvae :—hydrogen ion concentration, carbon dioxide,

TABLE II.

Giving values of organic nitrogen, as parts per 100,000, and number of occasions on which larvae of *Anopheles tarsimaculatus* were found in association.

Organic nitrogen	Number of larvae						Total occasions	Mean larvae
	nil	1-5	6-10	11-15	16-20	21 & up		
over 0.50	7	2					9	0.6
0.45—	6	2					8	0.75
0.40—	9	2	2				13	1.69
0.35—	4	4	0	1	0	2	11	9.24
0.30—	9	6	1	2	1		19	3.68
0.25—	12	8	9	0	1	1	31	4.91
0.20—	21	16	7	3	1		48	3.35
0.15—	9	22	9	3	3	4	50	7.68
0.10—	24	30	20	4	5	2	85	5.51
0.05—	8	11	5	3			27	4.15
0.00—	2	1	2	4			9	7.89
Total ...	111	104	55	20	11	9	310	

dissolved oxygen, nitrites, nitrates, phosphates, chlorides, and total solids. I have confirmed her conclusion in several instances by determining the mean number of larvae found with certain concentrations of the chemical factor. It seems unnecessary to publish the results. Table III may be taken as a sample of them ; it shows that with increasing values of phosphorus there is no tendency for the mean number of larvae to rise or fall.

The conclusion is perhaps justified that ammonia nitrogen has a greater effect upon the numbers of larvae in Trinidad than any other of the factors which were studied, but this does not tell us how the chemical factor may be supposed to act. Its effect may be upon the female, deterring her from depositing eggs in water in which the contamination is above a certain figure. Alternatively, it may be upon the larva, which may be killed by traces of ammonia or some other substance. Beattie exposed larvae of *Anopheles tarsimaculatus* to higher concentrations of ammonia than occurred

in nature, and they "throve well" at 0.1 to 0.2 parts per 100,000. This supports the view that the effect which she observed was due to ammonia repelling the female, but I should prefer to see further tests, particularly upon very young larvae, before I accepted this. It would be valuable to establish the upper limit of ammonia which larvae tolerate, for the ammonia ion is so active that one might suppose that a low concentration would be fatal. It seems that we do not know the concentration of ammonia or other products of decomposition which are harmful or lethal to any aquatic insect. It is, of course, familiar that organic effluents from sewers, beet-sugar factories, creameries and many other commercial establishments are fatal to aquatic plants and animals.* It is believed that, in most cases, death is due to lack of oxygen, though certain products of decomposition are doubtless toxic. But it is clear that lack of oxygen in the contaminated water cannot be unfavourable to the larvae of *Anopheles* or any other creature which breathes at the surface. Furthermore,

TABLE III.

Showing the mean number of larvae found associated with different values of phosphorus expressed as parts of P_2O_5 per 100,000 (310 determinations).

P_2O_5	under .002—	.002—	.004—	.006—	.008—	.010—	.012—	.014—	.016—	.018—	.020—	.024	.030
Total occasions	116	67	51	6	6	22	2	13	9	4	6	6	2
Mean larvae	4.97	4.42	6.67	4.50	2.83	5.54	1.50	7.15	2.56	4.00	3.17	2.83	26.50

it must be admitted that we do not know whether the ammonia itself is effective, or whether it is only a measure of some other more subtle product of decomposition. These questions can hardly be decided by work in the field, but some relatively simple experiments in the laboratory should be able to answer them.

Reference.

BEATTIE, M. V. F. 1932. The physico-chemical factors of water in relation to mosquito breeding in Trinidad.—Bull. Ent. Res., **23**, pp. 477–496.

*Information on this subject is summarised monthly in "Water Pollution Research," published by the Department of Scientific and Industrial Research.

NEW INJURIOUS CURCULIONIDAE (Col.) FROM TANGANYIKA.

By Sir GUY A. K. MARSHALL.

Subfamily OTIORRHYNCHINAE.

***Sphrigodes globulus*, sp. n.**

♂♀. Derm piceous, shiny, with dense grey scaling more or less mottled above with dark brown patches.

Head somewhat flattened dorsally, with a deep oval frontal fovea, fairly dense scaling, and subrecumbent spatulate setae. *Rostrum* twice as long as the head, parallel-sided from the base to the antennae, with a broad bare lateral carina running from the eye to the lower edge of the scrobe, and three narrow dorsal carinae, of which the outer ones converge strongly from the base to the antennae; the inter-antennal area sub-triangular and shallowly impressed, its narrowest part less than half the width of the forehead; the epistome twice as broad as long. *Antennae* with the scape slender, straight and abruptly clavate; the funicle with joints 1 and 2 equal or 2 slightly longer, 3-6 becoming progressively shorter, 7 as long as 4. *Prothorax* 1.5 times as broad as long, widest at the strongly arcuate base, very rapidly narrowed in front with the sides almost straight, not constricted at the apex, which is half the width of the base; the dorsum slightly convex longitudinally and sloping very steeply from base to apex, with distant punctures containing a recumbent spatulate seta. *Elytra* a little broader than long (♂) or slightly longer than broad (♀), widest at one-third from the base, the lateral area above the metasternum being much more inflated than usual, not constricted at the base, which is deeply sinuate and not carinate and has a small bare spot on each side of the suture; the dorsal outline extremely convex, almost semicircular, highest at only one-third from the base and sloping almost as steeply in front as behind, the declivity at the apex perpendicular; elytra not striate, but with 18 or 19 regular rows of numerous small punctures which are visible through the scaling and do not diminish behind; the normal intervals indicated by a row of short spatulate setae, which are recumbent in ♂ and more or less erect in ♀. *Legs* with dense grey scaling, the femora with an indefinite darker patch below the middle; the hind tibiae with a row of long stout teeth internally; joint 2 of the hind tarsi longer than broad. *Venter* not granulate, the last ventrite of ♀ with an obtuse median costa at the apex.

Length 3.2-4.5 mm., *breadth* 2.5-3.1 mm.

TANGANYIKA TERRITORY: Masasi, 10♂♂, 6♀♀, defoliating ground-nuts and sesame, i.1934 (*W. Victor Harris*).

Differs from all its known congeners in its hemispherical form, with the elytra widest before the middle and bearing numerous rows of punctures. The typical species of *Sphrigodes* have only 10 rows, but *S. variegatus*, Hartm. 1904, has 15-16.

***Sphrigodes crinitus*, sp. n.**

♂♀. Derm piceous, densely clothed above and below with uniform pale greenish-grey scaling having a slight opalescent reflection, but often concealed by a thin earthy coating above.

Head with the scaling on the forehead erect and matted, concealing the sculpture and also the incision separating the rostrum, with three erect setae adjoining each eye; when scraped the forehead bears a fine low median carina continuous with that on the rostrum; the eyes almost flat. *Rostrum* rather long and slender, slightly narrowing from the base to the antennae, clothed like the forehead; when bare, with

a sharp median carina and two lower ones on each side of it, also another in a line with the lower margin of the eye; the epistome very steeply declivous, bounded behind by a low curved carina in ♀, which is much higher and sharper in ♂, with its outer angles projecting upwards. *Antennae* with the scape slender, gradually clavate, densely squamose, and with suberect setae; the funicle with the two basal joints equal, 3-6 progressively shorter, 7 as long as 4. *Prothorax* 1.3 times as broad as long, moderately rounded laterally, widest at about the middle, not constricted at the apex, which is three-fourths the width of the slightly arcuate base; the dorsum convex longitudinally and sloping steeply forwards, with matted erect scaling and a few long erect setae; when the scaling is removed, the surface is covered with very small isolated granules and there is a broad transverse impression behind the apex. *Elytra* similar in the two sexes, ovate (5:4), not constricted at the base, which is shallowly sinuate, widest a little before the middle; the dorsal outline convex, sloping towards the base and not continuous with that of the pronotum; the striae almost concealed by the dense scales, which are concave and overlap, the intervals appearing broad and each with a row of long stout sharply-pointed erect setae; a small prominent shiny bead-like granule on each side of the suture at the base; when the scaling is removed, the striae are seen to contain large round separated punctures. *Legs* with dense uniform scaling; the tibiae not denticulate, or at most with two or three rudimentary denticles, the front pair somewhat curved inwards at the apex.

Length 2.7-3.5 mm., breadth 1.5-1.7 mm.

TANGANYIKA TERRITORY: Morogoro, 8♂♂, 3♀♀, on simsim (*Sesamum indicum*), iv.1924, v.1926 (A. H. Ritchie).

This is the smallest species in the genus and the only one known to me which bears erect setae.

Mr. Ritchie has also forwarded another weevil which attacks *Sesamum*, namely, *Phacemastix picta*, Hesse 1928, of the subfamily BARIDINAE, which occurs also in the Transvaal, Cape Province, and South West Africa.

***Icaniris contropus*, sp. n.**

♂♀. Derm black, with moderately dense sandy-grey scaling.

Head of ♂ densely squamose throughout dorsally, that of ♀ with a broad shiny bare stripe on each side of the median sulcus, which is rather broad and deep; the eyes moderately convex, highest slightly behind the middle. *Rostrum* a little longer than broad, separated from the head by a curved furrow that is almost interrupted in the middle, the apex slightly wider than the base, especially in ♂, the sides sinuate; the dorsal area somewhat narrowed in front, with a strong median carina and angulate laterally, separated anteriorly by a low transverse ridge from the interscrobular area, which is almost impunctate and bears a large median impressed triangle, the epistome defined posteriorly by a sharp semicircular carina. *Antennae* slender, elongate; the scape gradually clavate; joint 1 of the funicle a little longer than 2+3, 3 much longer than 4, 4-7 subequal, elongate and clavate. *Prothorax* somewhat transverse (5:6), moderately rounded laterally, widest beyond the middle, shallowly constricted near the apex, which is rather narrower than the truncate base; the dorsum gently convex longitudinally, highest behind the middle, rather sparsely set with low rounded granules in the middle of the disk which rapidly become much smaller laterally, where they are almost hidden by scaling; no median stria or carina, the setae short and erect. *Elytra* narrowly ovate and broadest near the base in ♂, much wider in ♀ and less narrowed behind; the dorsal outline feebly convex anteriorly in ♂ and steeply declivous behind, slightly more convex in ♀ with the declivity steeper and almost perpendicular near the apex; the rows of punctures partly irregular and partly in confused pairs, the intervals between the pairs sometimes slightly higher in ♂ and with rows of minute granules, which are less evident in ♀; these intervals also with a

row of short erect setae. *Legs* rather densely squamose, all the femora with a fringe of long hairs beneath on the basal half in the ♂ only; and the front and hind tibiae with similar hairs throughout; the hind femora of ♂ with a stout tooth on the lower edge close to the base, and both the front and hind tibiae strongly curved in the apical half, but not dilated or denticulate.

Length ♂ 8.0–8.5, ♀ 8.0–8.7 mm.; breadth ♂ 3.0–3.4, ♀ 4.0–4.4 mm.

TANGANYIKA TERRITORY: Rungwe, 2♂♂, 4♀♀, on coffee, x.1931 (W. V. Harris); Mahenge, 2♂♂, 2♀♀.

This species is somewhat intermediate between the genera *Isaniris* and *Systates*, having quite the general facies of *S. exaptus*, Mshl. (Bull. Ent. Res. 11, 1920, pl. vii, f. 2), but with multiple rows of punctures on the elytra. Distinguished by the uneven granulation of the pronotum, the bare shiny frontal patch in the female, and especially the remarkable basal tooth on the hind femora of the male.

***Systates alticollis*, sp. n. (fig. 1).**

♀. Derm black, with metallic green scaling, which is fairly dense on the head, prothorax, and the sides of the elytra, but broken up into macular stripes on the disk of the latter; the underside with sparser green scales.

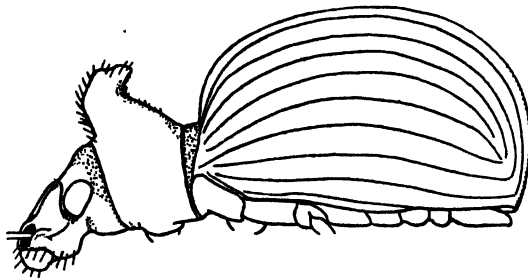


Fig. 1. *Systates alticollis*, sp. n., ♀.

Head finely aciculate where not covered by scaling, the median sulcus narrow and deep; the eyes moderately convex, highest close to the posterior margin. *Rostrum* about as long as broad, separated from the head by a curved furrow, the apex and base of about equal width, the sides shallowly sinuate; the dorsal area almost parallel-sided, finely aciculate, impunctate, sharply carinate laterally and with a shallow impression on each side of the low median carina; the inter-antennal area scarcely declivous, flat, finely rugulose. *Antennae* with the scape long, very slender, abruptly clavate, with narrow green scales and recumbent setae; the joints of the funicle in order of length: 1, 2, 3, 4 (5, 6, 7). *Prothorax* transverse (2:3), moderately rounded at the sides, widest at the middle, shallowly constricted near the apex; the base truncate, narrowly marginate, scarcely wider than the apex; the dorsum bearing in the middle a stout erect column, which rises to a height of 0.75–0.85 mm. vertically above the front margin and is produced backwards at its apex into a broad bifurcation, below which it slopes very steeply to the base; the finely rugulose surface mostly hidden by scaling, but the upper part of the column with minute shiny granules, and a bare median sulcus on the posterior slope. *Elytra* broadly ovate, strongly rounded laterally, widest a little before the middle, obtusely rounded behind; the dorsal outline very strongly convex, highest at the middle, sloping vertically near the immarginate base and also on the declivity near the apex; the shallow striae containing large subquadrate transverse punctures, each having a minute granule on its anterior edge; the intervals smooth, with sparse erect pale setae. *Legs* unevenly clothed with green scales, the hind tibiae of ♀ slightly curved, and with only minute granules on the inner face; joint 2 of the hind tarsi as long as 3.

Length 6-7 mm., breadth 3.0-3.5 mm.

TANGANYIKA TERRITORY: Tunduru, 4♀♀, on groundnuts, ii.1932 (W. V. Harris).

A very remarkable species on account of the striking bifurcate prominence on the pronotum.

***Systates annulatus*, sp. n.**

♂♀. Derm dull piceous black, sparsely and unevenly clothed with golden or grey hair-like scales, with patches or spots of slightly broader scales; the pronotum with a narrow broken whitish stripe on each side; the elytra with rows of small white spots on the lateral intervals, one spot behind the middle on interval 7 and another on the declivity on interval 3; the ♀ with a transverse gold or whitish patch at the top of the declivity, reaching stria 3 on each side and extending backwards for some distance along interval 1; in the ♂ this marking is replaced by a small white dot above the declivity on interval 3; the hind femora with a white ring on the apical half, and much less distinct rings on the other femora.

Head aciculate, impunctate; the forehead quite flat, with a deep median furrow extending back as far as the hind margin of the eyes, which are very convex and deepest behind the middle. *Rostrum* as long as broad, separated from the head by a transverse sulcus, as wide at the genae as at the base, with the sides sinuate; the dorsal area almost parallel-sided, hardly separated anteriorly from the inter-antennal-area, sculptured like the head, tricarinate, the median carina narrow and flattened, and sometimes a trace of a fine sinuous oblique carina close to the lateral one; the inter-antennal area impressed, uneven, impunctate; the hind margin of the epistome obtuse. *Antennae* with the scape slender, curved, abruptly clavate, with a few hair-like scales and rather long subrecumbent setae; the funicle with the two basal joints equal, 3-6 progressively shorter, 7 as long as 3. *Prothorax* transverse (6:7), moderately rounded laterally, widest at a little beyond the middle, almost as wide at the apex as at the truncate base, not constricted apically; the dorsum only slightly convex longitudinally, highest behind the middle, with separated low round setigerous granules leaving a smooth median line; the pleurae with obsolescent elongate granules. *Elytra* broadly ovate in ♀, somewhat narrower in ♂ and jointly rounded at the apex, the apices in ♀ broadly rounded separately and produced downwards like a beak, the basal margin vertical but its upper edge not angulate; the dorsal outline slightly convex, the posterior declivity vertical near the apex in ♀ but not in ♂; the striae in part somewhat irregular, containing rather small round punctures, each bearing a very small low granule on its anterior edge; the intervals broad and flat with widely and unevenly spaced granules, which are low and round on the disk and conical posteriorly, each bearing a rather long fine erect seta. *Legs* with very sparse setiform scales in addition to the white rings on the femora; the front tibiae of ♂ curved towards the apex but the hairs like those of ♀, the hind tibiae sinuate internally on the apical half and there flattened and with two rows of small granules, those of ♀ less sinuate but with more prominent granules.

Length ♂ 7.5, ♀ 6.8-7.0 mm., breadth ♂ 3.0, ♀ 3.3-3.5 mm.

TANGANYIKA TERRITORY: Mfundu, Iringa, 1♂, 2♀♀, on tea, iv.1931 (W. V. Harris).

Apparently allied to *S. nigrogranatus*, Fairm. 1882, but in the description of that species no mention is made of erect setae, the granules on the pronotum are dense and those on the elytra oblong, and the head is punctulate.

***Systates minimus*, sp. n.**

♂♀. Derm piceous brown, with very sparse uneven scaling and erect spatulate setae.

Head aciculate or very finely rugulose, with a deep frontal furrow which extends well behind the eyes; the latter strongly convex, deepest somewhat behind the middle. *Rostrum* a little longer than broad, as wide at the genae as at the base, finely rugulose; the dorsal area quadrate, almost flat, tricarinate, separated by a deep transverse incision from the inter-antennal area, which is raised above it and more shiny, leaving a flattened median triangle; the epistome bounded behind by an obtuse semicircular ridge. *Antennae* with the scape slender, curved, abruptly-clavate, without scales, but with suberect setae; the funicle with the joints progressively shorter distally, 7 as long as broad in ♂, longer in ♀. *Prothorax* transverse (5:7), rounded at the sides, widest at the middle, not constricted at the apex, which is almost as broad as the truncate base; the dorsum convex longitudinally, highest behind the middle, fairly closely set with comparatively large low granules, without any median carina or stria; the pleurae coarsely punctate. *Elytra* ovate, a little broader in ♀, obtusely acuminate behind in both sexes, with a vertically truncate margin at the base; the dorsal outline moderately convex in ♂, a little more so in ♀, in which the declivity is vertical close to the apex, but not in ♂; the broad striae containing large close transverse punctures, which diminish behind; the intervals narrower than the punctures, smooth and impunctate, with sparse erect spatulate setae, some of which are pale and the others dark; the scales very small and narrow. *Legs* with only a few setiform scales towards the apex of the femora; the front and hind tibiae of ♂ with a fringe of long hairs beneath, the front pair sinuate internally near the apex, the hind pair moderately curved, flattened internally, but without any angulation or granules.

Length 2.5–2.7 mm., *breadth* 1.2–1.3 mm.

TANGANYIKA TERRITORY: Tukuyu, 2♂♂, 1♀, on butter beans, xii.1931 (W. V. Harris).

Much the smallest species of *Systates* known at present.

Subfamily TANYRRHYNCHINAE.

Goniorrhinus torrenus, sp. n. (fig. 2).

♂♀. Upper surface and the sides of the sternum normally covered with a deep layer of mud, but little or none on the venter and legs.

Derm testaceous brown, densely covered with sandy grey scales, which are paler and with a greenish tinge on the legs, front margin of the prothorax, and the head.

Head strongly narrowed in front so that the eyes appear to be situated on the base of the rostrum, the space between them deeply impressed and about as broad as an eye; the anterior part of the vertex broadly flattened, the space between the hind margin of the eyes and the prothorax being greater than that between the front margin of the eyes and the scrobes; the eyes subdorsal, flattened, with the inner edge higher than the forehead, the facetting almost obliterated superficially, so that the surface appears glassy. *Rostrum* normally held vertically downwards, not much longer than the elongate head (5:4), parallel-sided, almost straight, densely squamose above behind the antennae, usually bare laterally and beneath; the dorsum with a broad shallow longitudinal impression behind the antennae, the apical area saddle-shaped and sparsely squamose; the epistome almost perpendicular, flat, bounded behind by a transverse ridge; the scrobes shortly ovate, entirely dorsal, and separated only by a very thin lamina; the lower surface with sparse minute punctures. *Antennae* with the scape shortly exceeding the front margin of the prothorax, quite straight, densely squamose; the funicle with the two basal joints subequal, 3=4, 5–7 subequal, much longer than broad, 7 the widest. *Prothorax* strongly rounded at the sides, widest at one-third from the base, abruptly constricted and tubular at the apex, the constriction continuing equally across the disk, the base subtruncate

or feebly arcuate; the dorsum strongly convex longitudinally, highest behind the middle, much lower at the apex than at the base, with dense rounded scales, the apical margin with a fringe of densely overlapping elongate scales. *Elytra* sub-orbicular, moderately convex longitudinally on the dorsum, very steeply declivous behind, not striate, but with rows of small distant punctures, which are almost hidden by the scaling; on each side of the suture at the base a bare elevation, which is comparatively large and transverse in ♂, but small and punctiform in ♀, or even obsolescent; the intervals with a row of short erect setae. *Legs* densely squamose, the tibiae with a few small teeth on the inner edge, which are much larger on the hind pair of ♂ only, the front pair deeply sinuate internally near the apex.

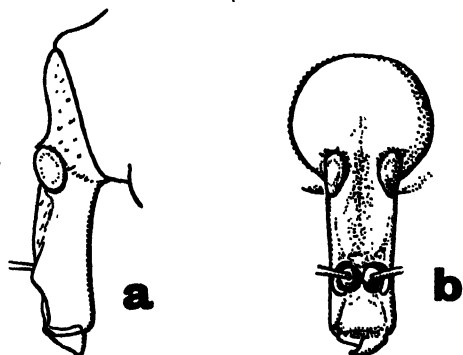


Fig. 2. Head of *Goniorrhinus terrenus*, sp. n.: a, lateral view; b, dorsal view.

Length 3.0–4.5 mm., breadth 2.0–3.0 mm.

TANGANYIKA TERRITORY: Kilosa, 19♂♂, 28♀♀, on cotton, iii.1934 (W. V. Harris).

The two previously described species of the genus, *erinaceus*, Fst. 1889, and *hardenbergi*, Mshl. (Bull. Ent. Res. 17, 1927, p. 214, pl. xix, f. 5) differ *inter alia* in having the head much shorter than the space between the eyes and the scrobes, and the vertex is not flattened perpendicularly, the rostrum is bent at the insertion of the antennae, the space between the scrobes is at least as wide as the shaft of the scape, the prothorax is widest at the base and has the sides almost straight, the elytra are shallowly striate and have no basal tubercles, and the tibiae are not denticulate.

NOTES ON DUTCH EAST INDIAN MOSQUITOS.

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Most of the mosquitos described here were collected by Dr. H. de Rook and the author during a tour of investigation of filariasis in the eastern part of the Malay Archipelago. The tour was undertaken with a grant from the "Koningin Wilhelmina Jubileum-Stichting" in Batavia.

I am much indebted to Dr. F. W. Edwards for useful advice and for granting me access to the collection of the British Museum.

***Megarhinus coeruleus*, sp. n.**

♀. Head with greenish metallic scales; a white margin to the eyes, reflecting bluish towards the vertex. Tori with flat scales on inner and posterior sides, the apical scales white, the basal ones dark brown; anterior sides of tori with a white tomentum. Lateral and posterior margins of clypeus with a white tomentum; centre black and nude. Palpi metallic purple, a pale purple band at one-third of the length from the base and minute pale purple spots at the apex. Proboscis: basal half shining coppery, apical half dark without metallic lustre.

Mesonotum and scutellum with metallic green scales, in the middle with a coppery hue. Anterior and lower border of anterior pronotal lobe with white flat scales, remainder black-scaled. Sternopleura with a patch of black, very narrow, small, flat scales near the middle of the anterior border. Other parts of pleura with broad, large, flat, white scales. Legs dark with purplish and coppery reflections. Inner sides of femora very pale gold-coloured. First and second tarsal joints of mid legs with broad, deep golden, basal bands. Hind legs without ornamentation. Wings: extreme base of costa with a patch of bluish metallic scales, other wing scales metallic purple. Longitudinal portion of *r-m* thrice as long as transverse portion.

Abdomen: first tergite with pale green metallic scales on the dorsal side and white, flat, outstanding scales on the lateral parts; tergites II and III metallic green, IV, V, and VI more bluish, VII and VIII purple; II-V with basal lateral patches of white scales, only visible from beneath, on VI and VII the patches continue on the dorsal side, most so on VII where they almost meet in the mid line. Sternites pale golden, VIII black in the middle, V, VI and VII with a small, median, black patch at the base. No lateral tufts at the apex of the abdomen.

♂. Tori unscaled, with white tomentum. Palpi as long as the proboscis, with purplish hue; apex of basal joint white-banded. Legs unbanded. Abdomen: first tergite dorsally golden at the apex, black at the base, white laterally. Venter mostly golden; sternites I-V black in the middle, a median black line thus being formed. Otherwise as female.

The difference in the scaling of the tori of the ♂ and the ♀ described here made me doubt whether the two are conspecific. However, on examination of the collection in the British Museum many *Megarhinus* species proved to show the same sexual dimorphism, *viz.*, tori scaled in the female, unscaled in the male; this was found in *M. acaudatus*, *M. splendens*, *M. quasiferox*, *M. speciosus*, *M. inornatus*, and *M. brevipalpis*. It recalls another instance in mosquitos where the female adornment is more elaborate than that of the male, the clypeus of *Aedes* (*Stegomyia*) *fasciatus*. In *Megarhinus aurifluus* and *M. edwardsi* both sexes show scaled tori. The tori of both sexes are unscaled in *M. magnificus*, *M.*

graveleyi, *M. albipes*, *M. kempi*, *M. klossi*, *M. leicesterei*, *M. metallicus*, *M. minimus*, *M. phytophygus* and *M. aeneus*. If present, the apical scales were always white and the basal ones dark.

Habitat.—One ♀ and one ♂ were reared from larvae found in *Nepenthes* by Jacobson in Batang Palupuh (West Coast of Sumatra). Type ♂ and ♀ in the British Museum.

M. coeruleus comes near *M. acaudatus*; it can be distinguished easily by the quite different colour of the dorsum of the abdomen. In *M. acaudatus* the tergites are purple above, the golden lateral patches are equally large on tergites II–VI and smaller on VII.

***Megarhinus amboinensis*, Dol.**

Specimens were reared from larvae found in bamboo in Warasiwa and Hoelong

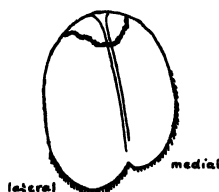


Fig. 1. *Megarhinus amboinensis*, paddle of pupa.

(N. coast of Ceram). The pupal paddle (fig. 1) is almost identical with that of *M. quasiferus* as figured by Edwards (Bull. Ent. Res., 17, p. 114).

Genus *Tripteroides* (syn. *Rachlonotomyia*).

Edwards (Nova Guinea, 15, p. 352) described five new species of this genus from female specimens collected by Dr. Docters van Leeuwen in New Guinea at altitudes ranging from 400 to 2,400 metres. A curious feature of this collection was that it contained, besides *Armigeres lacuum*, *Tripteroides* specimens only, belonging to six species, of which five were new; the sixth was *T. bimaculipes*.

In 1932 Dr. de Rook and the author spent half a day in collecting mosquito larvae from *Nepenthes* in Tanah Merah on Upper Digoel River (South New Guinea). The *Nepenthes* grew plentifully in brushwood not higher than 2.5 m. The bowls hardly contained any water at the time of collecting, only 1 or 2 ccm. of mud at the bottom, in which the larvae crawled. When the larvae were placed in water they rarely rose to the surface; mostly they crawled around at the bottom of the vessel without showing the typical wriggling motion. *Tripteroides* only were reared from the larvae, belonging to five species which all proved to be new. No specimens of the species described by Edwards in 1927 were obtained.*

In the *Nepenthes* bowls there were besides the mosquito larvae many dead bodies of metallic green ants. Apparently the same ants abounded in the bush; their biting was a great nuisance to the collectors. Possibly their bodies serve as food for at least some of the larvae. The powerful maxillae (*Rachisoura*-type) of some of the larvae (fig. 3, b) might very well serve to destroy the bodies.

I have refrained from arranging the new *Tripteroides* into the subgenera recently proposed by Edwards (Genera Insectorum, fasc. 194, p. 75). According to Edwards' system the male of *T. brevirhynchus* would come into the subgenus *Tripteroides* and its larva into *Rachisoura*.

* In 1928 Dr. de Rook collected some larvae of *Megarhinus speciosus* from *Nepenthes* in the same bush.

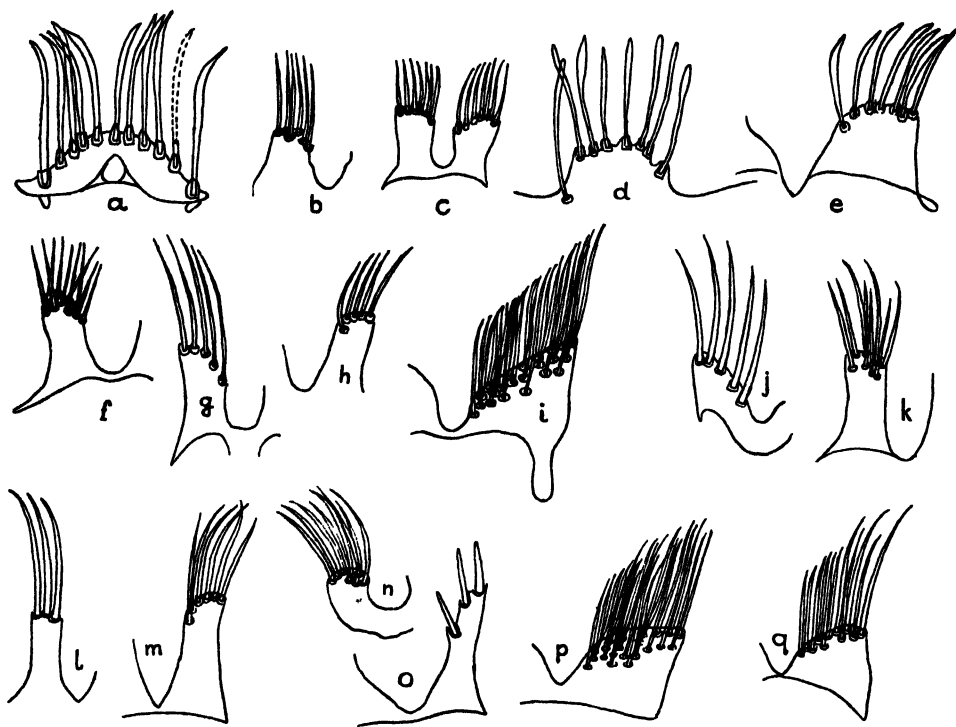


Fig. 2. Ninth tergites of *Tripteroides*: a, *T. brevirhynchus*; b, *T. digoeiensis*; c, *T. papua*; d, *T. simplex*; e, *T. sylvestris*; f, *T. brevipalpis*; g, *T. obscurus*; h, *T. bimaculipes*; i, *T. vicina*; j, *T. atripes* var. *occidentalis*; k, *T. bimaculipes*; l, *T. powelli* (?); m, *T. powelli* var. *indica*; n, *T. argenteiventris*; o, *T. aranoides*; p, *T. plumosa*; q, *T. proxima*.

***Tripteroides brevirhynchus*, sp. n.**

♀. Head with flat dark brown scales above, creamy scales laterally, the latter extending medially as a creamy border to the eyes, narrowing towards the middle. Clypeus and tori dark brown; clypeus with some 2 to 4 scales on each side. Proboscis and palpi black; proboscis short and stout, two-thirds as long as the abdomen, three-fourths as long as the fore femur and 6 times as long as the palpi.

Mesonotum with narrow scales, mostly dusky brown and a few greyish white ones at the frontal margin; scutellar scales dark brown; two pairs of bristles at the frontal margin, two pairs of prescutellar ones. Anterior pronotal lobes with creamy flat scales, posterior with grey flat scales; no posterior pronotal bristle; usually 3-4 spiracular bristles, sometimes 5-6; upper sternopleural bristles absent; pleura densely covered with flat creamy scales. Wing: scales rather broad on the first and second veins and on the basal parts of the other veins, narrow on the apical parts of the 3rd to 6th veins. Anterior fork cell 2.3 times as long as its stem, posterior 1.5 times; base of former usually nearer the wing base, sometimes level, rarely that of anterior cell nearer wing base. In one specimen a curious malformation of the wing venation was seen; on both sides the apical parts of the sixth vein were missing. In another specimen there was a hiatus pre-apically in the sixth vein of the left wing, the right wing being quite normal. Legs dark brown. Hind tibia much shorter than the middle one (2:3). Two hind tarsal claws present.

Abdominal tergites dark brown with triangular creamy apical, lateral patches, venter creamy; border-line serrate.

♂. Antennae plumose. Palpi, proboscis and clypeus as in the female. Coloration and chaetotaxy as in the female. Hypopygium: 9th tergite not emarginate in the middle (lobes grown together), 4–6 broad hairs on each side (fig. 2, a).

Larva.—Head round; antenna short, straight, tuft consisting of one short simple hair near the tip; clypeal hairs small, bifurcated or simple; maxilla stout, with five strong curved teeth at the apex, gradually decreasing in size (fig. 3, a); mentum narrow, with 11 teeth, those next to the mid one being the smallest. Body covered with stellate hairs, as in *T. aranoides*, points of the branches of the hairs simple. Comb of VIIIth segment consisting of one tooth only (fig. 3, b). Siphon: index a bit more than 2; pecten of 4 teeth, the extreme one at the apex of the siphon; ventral hairs on each side, successively, a small bifid hair, a large feathered bifid hair, a simple large hair, and a small bifid hair; on the dorsal side there are on each side three or four feathered hairs with two or three branches (fig. 3, c). Anal segment: saddle covering more than half the segment; outer dorsal hair simple, inner with two branches; lateral hair with three or four branches, only a little shorter than the dorsal hairs; anal fan consisting of a pair of 4- or 5-branched hairs. All the hairs on the anal segment feathered.

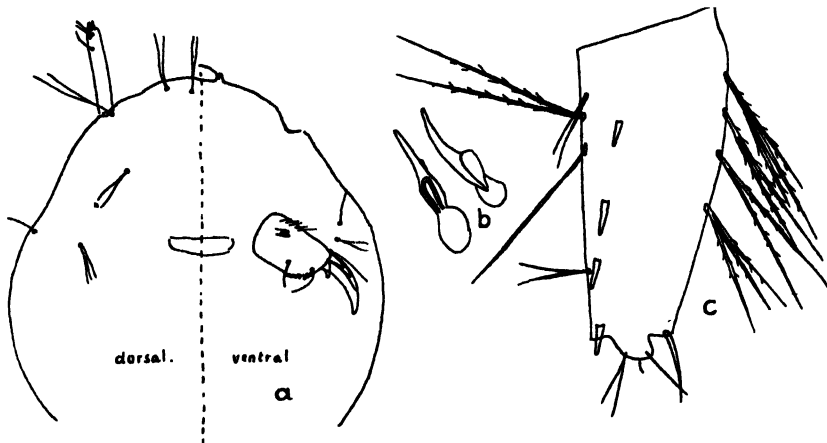


Fig. 3. *Tripteroides brevyrhynchus*, larva: a, head; b, comb scale, front and side view; c, siphon.

Pupa.—Paddles very short, broader than long, about half as long as the 8th abdominal segment; unequally divided by the rib, the lateral portion being the larger; with minute spines on the lateral part of the apex. Large apical tufts on 8th abdominal segment thrice as long as the paddles, each consisting of 15–18 feathered branches.

Habitat.—Larvae found in *Nepenthes*; Tanah Merah, Upper Digoel R., New Guinea.

Description from a great number of females and males and three larval skins.

The imago somewhat resembles *T. vanleeuweni*; it differs from the latter by having the clypeus scaled, a shorter proboscis, shorter palpi, less spiracular bristles and two claws on the hind tarsus.

Types, ♂ and ♀, in British Museum; cotypes, ♂ and ♀ in Instituut voor Tropische Hygiene, Amsterdam.

***Tripteroides obscurus*, sp. n.**

♂. Head all black-scaled on upper side. Clypeus, tori, palpi and proboscis black. Palpi one-third as long as proboscis. Proboscis short, stout, about three-fourths as long as fore femur. Antennae plumose.

Mesonotal scales dark brown, in the middle narrow, laterally rather broad. At least one pair of prescutellar bristles present. Posterior pronotal lobe mostly with dark brown scales, some grey ones on the lower margin. One black posterior pronotal bristle; upper sternopleural absent; three black spiracular ones; pleura thickly covered with greyish white flat scales, except, as usual in this group, the anterior part of the sternopleura. Wings with outstanding scales narrow, almost linear. Anterior fork-cell somewhat more than twice as long as its stem; posterior 1.67 times as long; base of the former nearer the wing base. Legs all dark brown. Hind tibia four-fifths as long as the middle one.

Abdomen: upper side dark brown, underside creamy; borderline straight. Hypopygium: 9th tergite with a U-shaped incision, lobes rather slender, each with 5 hairs; the latter longer than the lobes (fig. 2, g). Basal lobe of coxite with four very long hairs (fig. 4, c).

Habitat.—As *T. brevirhynchus*. Described from one male. Type in British Museum.

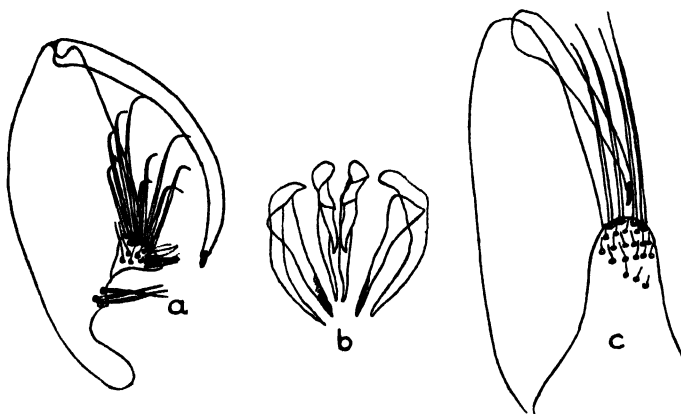


Fig. 4. *Tripteroides papua*: a, coxite; b, mesosome and paraprocts, compressed. *Tripteroides obscurus*: c, coxite.

Rather like *T. vanleeuweni*, but differing in having the head scales all black on the dorsal side, the abdominal colours separated by a straight line and a posterior pronotal bristle. *T. obscurus* may be easily distinguished from *T. papua* by the narrow wing scales and the different structure of the hypopygium.

One male specimen from the same breeding-place differs from the description given above in that the borderline of the abdominal colours is serrate. The hypopygium is identical with that of *T. obscurus*. It is possible that *T. obscurus* is none other than the male of *T. vanleeuweni*, although Edwards describes the latter as having no posterior pronotal bristle.

***Tripteroides papua*, sp. n.**

♀. Head dark brown, no pale rim to the eyes. Clypeus, tori, palpi and proboscis black. Proboscis three-fourths as long as abdomen, nine-tenths as long as fore femur, four times as long as palpi.

Mesonotum with moderately narrow, rather small, dark brown scales and a very small patch of white scales medially on the front margin. One pair of prescutellar bristles. Pleural scales creamy, except on both the pronotal lobes, the dorsal parts of which are brown-scaled. One posterior pronotal bristle, no upper sternal, 2-3 black spiracular bristles. Wing scales all broad, dark brown. Both fork-cells twice

as long as their stems; bases level. Legs dark brown. Hind tibiae not much shorter than mid ones (7 : 8). Abdomen: Tergites dark brown with creamy lateral apical triangular patches; sternites creamy. Borderline between the colours serrate.

♂. Palpi a bit less than one-third as long as proboscis, the latter as long as fore femora. Antennae densely plumose, four-fifths as long as proboscis. Base of posterior fork-cell nearer to the wing-base than that of the anterior. Otherwise as female. Hypopygium: Basal lobe of coxite with about 9 large hairs and many small ones. Still nearer the base of the coxite there are 3 conspicuous horizontally directed hairs (fig. 4, a). Lobes of 9th tergite parallel-sided, each with 7–12 hairs, the latter about as long as the lobes; a deep U-shaped incision between them (fig. 2, c). Whereas in most *Tripteroides* the apex of the paraprocts is directed towards the apex of the hypopygium and provided with 3–6 strong, black, somewhat claw-like teeth, in *T. papua* such a structure is absent. Perhaps the slender chitinous projection directed towards the base of the hypopygium and showing one black tooth (fig. 4, b) is the homologue of the paraproct.

Habitat.—As *T. brevirhynchus*. Description from 3 males and 2 females. Types, ♂ and ♀, in British Museum.

This species much resembles *T. latisquama*. It differs by the paler colour of the pleural and abdominal scales, the absence of sternopleural bristles and the smaller number of spiracular bristles (2–3 as against 5–6) and of prescutellar bristles (1 pair as against 5–6 pairs).

***Tripteroides atripes* var. *occidentalis*, nov.**

♂. Head with very pale, greyish brown, flat scales and a creamy coloured border to the eyes; a row of dark brown forked scales behind on the nape; lateral parts white-scaled. Clypeus, tori, palpi and proboscis black, except the base of the palpi and of the proboscis which are pale creamy. Palpi in two specimens four-fifths and five-sixths as long as the proboscis.

Mesonotal integument brown, scales narrow and mostly very pale brown, but creamy white on the sides and before the scutellum. Scutellar scales flat, creamy white. Pleural scales flat and white; one small pale posterior pronotal bristle visible. Wings brown-scaled; outstanding scales narrow; anterior fork cell 2.5 times as long as its stem, posterior not quite twice as long; base of the former nearer the wing-base. Legs: inner sides of femora, and basal two-thirds of fore femora on all sides, and inner sides of tibiae yellowish; rest of legs graduating from brown femora to dark brown tarsi.

Abdomen: tergites dark brown, with apical, triangular, creamy white, lateral patches, continued medially so as to form interrupted apical bands on the basal segments and complete bands on the apical segments; the latter bands are narrowest in the middle. Hypopygium: lobes of ninth tergite somewhat triangular, rather low, each with five strong, long bristles, the median bristles implanted near the bottom of the incision (fig. 2, j).

Habitat.—Timor; 2 males caught by Dr. Overbeek in Atapoepe, one by Dr. van Rees in Oebe. Type in the British Museum.

This variety differs from the typical *T. atripes* and from the variety *puncto-lateralis* mainly in the pale scaling of the base of the palpi and proboscis, of the head, of the mesonotum and of the scutellum. It is more extensively pale-scaled than any other *Tripteroides* without white patches on the legs; in no other species of this group do the lateral patches extend so far dorsally up the abdomen as in this variety.

***Tripteroides digcolensis*, sp. n.**

♂. Head with black scales and a creamy coloured rim to the eyes, broadest laterally. Palpi and proboscis black. Length of palpi three-fourths that of proboscis. The latter as long as the fore femora.

Mesonotum with dark brown, rather small, curved scales, with 3 pairs of bristles on the anterior margin, but without prescutellar bristles. Pleura with white flat scales. One posterior pronotal black bristle. Three yellow spiracular ones. No upper sternopleural bristle. Wing: outstanding scales linear. Anterior fork-cell 3.5 times as long as its stem; posterior twice as long; base of the former nearer the wing-base. Legs dark brown, posterior pair missing.

Abdomen dark brown dorsally, whitish beneath, the colours separated by a straight line. Hypopygium: basal lobe of coxite with eight moderately long hairs, the tips of the hairs not quite reaching the level of the apex of the coxite. The lobes of the 9th tergite separated by a deep, U-shaped incision; each lobe with 6 hairs, the latter a little longer than the lobes (fig. 2, b).

Habitat.—As *T. brevirhynchus*. Described from 1 male. Type in the British Museum.

This species differs from *T. brugi* by the spiracular bristles being yellow, by the absence of an upper sternopleural bristle and by the very long anterior fork-cell. The long palpi distinguish it from the other species described above.

***Tripteroides simplex*, sp. n.**

♂. Head dusky brown on dorsal side. Tori and clypeus black. Palpi and proboscis also. Palpi exceeding the clypeus by a bit more than its length. Proboscis short and stout, nine-tenths as long as the fore femur, apex thickened.

Mesonotum: integument and scales dark brown, the scales rather narrow. Pleura thickly clothed with whitish scales; posterior pronotal sternopleural bristles absent; three black spiracular bristles.

Abdomen: dark brown on upper side, creamy white beneath, the colours being separated by a serrate line. Legs dark brown. Wings dark brown-scaled, outstanding scales narrow. Anterior fork-cell twice as long as its stem, posterior 1.5 times as long. Base of the former nearer the wing base. Wing length 2.5 mm.

Hypopygium: basal lobe of the coxite with 9 large hairs, the hairs relatively short, covering about half the distance to the apex of the coxite; 9th tergite with one median lobe only with 8 rather long, more or less spoon-shaped hairs (fig. 2, d).

Habitat.—As *T. brevirhynchus*. Description from one male. Type in the British Museum.

This species is very similar to *T. brevirhynchus*, even in the structure of the hypopygium, but its palpi are shorter (in the latter species they exceed the clypeus by twice its length and its clypeus is unscaled). From *T. brugi* it is to be distinguished by the serrate separation between the colours of the abdomen, and by the absence of posterior pronotal and sternopleural bristles.

***Tripteroides elegans*, sp. n.**

♀. Head with a band of blue scales, not quite covering half its breadth; basal part of the head black. Tori dark brown; clypeus black. Palpi and proboscis black. The palpi exceeding the clypeus by a little more than its length. Proboscis about as long as the abdomen.

Mesonotum: integument black, shining bluish, with black narrow scales. Scutellum with black flat scales. Anterior pronotum with yellowish integument and black narrow scales. Sternopleura and mesepimeron with many flat silvery scales. Three spiracular bristles. Wings dark brown-scaled, outstanding scales moderately broad; anterior fork-cell 1.5 times as long as its stem; posterior a little more than 1.5 times; the base of the latter nearer the wing-base. Legs: anterior femora with two white patches on the basal half and a white line on the apical half; in some lights these ornaments are bright blue. Mid and hind femora with two white patches on the basal half, not blue in any position.

Abdominal tergites dark brown with silvery, white, lateral ornamentation; on II a lateral patch over the whole length of the segment; on III a very small apical patch; IV-VI with much larger apical patches. Venter: the last segments golden with black apical bands, other ones invisible.

Habitat.—One female specimen caught near Torpedoboot River, New Guinea, by Dr. Baardmans. Type in British Museum.

Differs from *T. littlechildi* principally in the abdominal ornamentation. In *littlechildi* there are very large silvery areas on tergites II, IV and V and small silvery paramedian lines on III, VI and VII.

***Tripteroides brevipalpis*, sp. n.**

♀. Head with the characteristic broad band of blue scales to the eyes. Tori yellowish brown, clypeus dark brown, palpi and proboscis black. Palpi exceeding the clypeus by its length. Proboscis 1.5 times as long as the abdomen, about 14 times as long as the palpi.

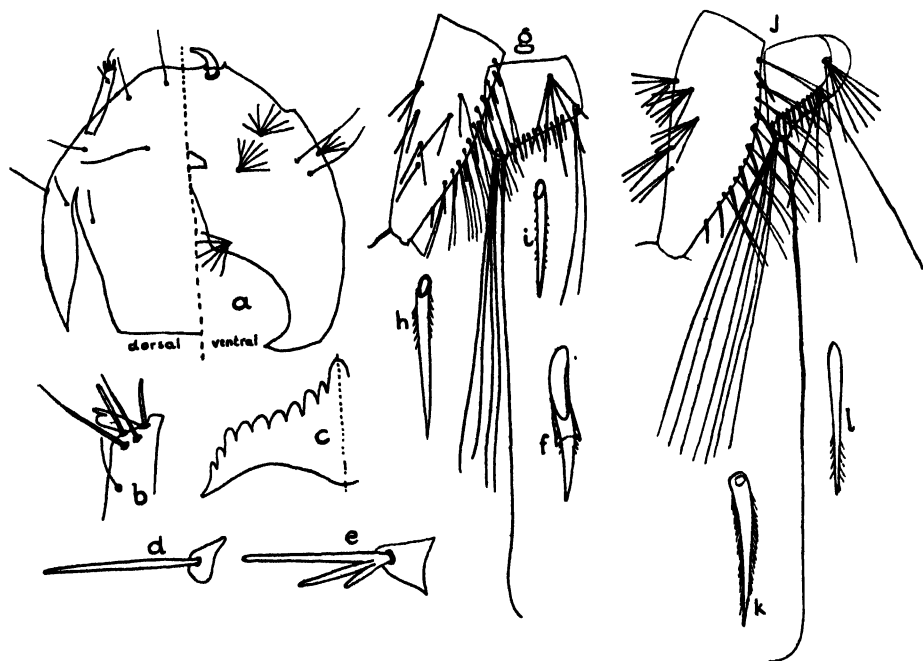


Fig. 5. *Tripteroides brevipalpis*, larva: a, head; b, tip of antenna; c, mentum; d, mesothoracic lateral spine; e, metathoracic lateral spine; f, comb tooth; g, siphon and anal segment; h, pecten tooth; i, spine on anal segment. *Tripteroides bimaculipes*, larva: j, siphon and anal segment; k, pecten tooth; l, spine on anal segment.

Mesonotal integument dirty yellow, clothed with long narrow black scales. Anterior pronotal lobe with flat black scales, posterior with hair-like black scales. Pleurae dark brown with many flat silvery scales. Legs blackish brown with silvery, white ornamentation. Anterior femur with a narrow golden line on the apical half and two silvery patches on the basal half; mid femur with two silvery patches apically and a silvery line basally; hind femur with a preapical silvery patch and a broad silvery stripe at about the middle. Hind tibia about equal in length to the middle one. Wings dark brown-scaled, the outstanding scales ligulate. Anterior fork-cell 1.4 times as long as its stem, posterior not quite 1.3 times as long; their bases level.

Abdomen compressed ; tergites with silvery apical bands, interrupted medially, broadening laterally ; sternites golden.

♂. Antennae plumose ; otherwise, palpi too, as in the female. Hypopygium : lobes of 9th tergite longer than broad, separated by a deep, sinuous, more or less V-shaped incision ; each lobe with about ten spiny hairs, the hairs slightly shorter than the lobe (fig. 2, *f*).

Larva.—Head round, antenna short, straight ; antennal tuft consisting of a simple small hair, implanted near the apex ; hairs on the ventral side mostly stellate (fig. 5, *d*). Thorax and abdomen thickly covered with black stellate hairs, giving the larva a black appearance ; the hairs are 14–18-branched, the branches do not decrease in thickness towards their apices ; the latter have two or sometimes more points, as if fractured. Metathoracic lateral spine 3- or 4-branched, mesothoracic spine simple (fig. 5, *d*, *e*). Comb of eighth abdominal segment consisting of 14 teeth in one row, the teeth with a fine short fringe at their bases (fig. 5, *f*). Siphon (fig. 5, *g*) : index 3 ; pecten of 9 teeth (fig. 5, *h*), distributed over almost the whole length ; about 10 bifid ventral hairs ; on the dorsum and the lateral sides of the siphon there are some irregularly distributed bifid and simple hairs resembling the stellate hairs on the thorax and abdomen. Anal segment (fig. 5, *g*) with a large saddle ; inner dorsal hairs 4-branched, outer dorsal simple, lateral hair long, bifid ; anal fan represented by a pair of 5-branched hairs with stiff branches ; apical side of the saddle with a row of fairly long spines (fig. 5, *i*). All the hairs on the siphon and the anal segment feathered.

Pupa.—Almost the whole pupa is brown pigmented. The paddles a little longer than the eighth segment and pale ; the rib pigmented ; the part lateral to the rib longer and broader. Eighth abdominal segment with a pair of lateral fans a little longer than the paddles, each consisting of 16 feathered branches, and a simple hair nearly one-third as long.

Habitat.—Larvae found in bamboo-stumps and in cut bamboo in various places (Warasiwa, Oewin, Hoelong) on the North Coast of Ceram (Moluccas). Description from 4 males and 5 females and 2 larval skins. Type, ♂ and ♀, and larval skin in the British Museum.

T. brevipalpis differs from *T. coeruleocephala* only in having smaller palpi, these structures exceeding the clypeus in the latter species by twice its length. From *T. bimaculipes* and *T. littlechildi* the species differs in having the integument of the mesonotum dirty yellowish, as against dark brown and black in *bimaculipes* and *littlechildi*.

Tripteroides bimaculipes, Theo.

The larva of this species, hitherto undescribed, is very similar to that of *T. brevipalpis*, only differing in the branching of the hairs and the length of the teeth on the siphon and anal segment. The hairs on the dorsum of the siphon are 2–6-branched, the inner dorsal hair on the anal segment has 7 branches, the lateral hair 4 branches and the hair representing the anal fan 6 branches. The teeth of the pecten are longer, as are the spines on the apical border of the anal saddle ; the teeth of the pecten are also more densely fringed (fig. 5, *j*, *k*, *l*).

Larvae of this species were found on the North Coast of Ceram (Moluccas), in the Island of Saparoea (near Ceram), near Upper Digoel River (South New Guinea) in a coconut husk, in a tree-hole, in bamboo stumps and in *Nepenthes*. Description from 2 larval skins.

Tripteroides argenteiventris, Theo.

Many males and females were bred from larvae found in the axillae of the small leaves at the feet of the flowers of a *Curcuma* together with those of *Uranotaenia*

diagonalis (see below). The palpi of the *male* are seven-tenths as long as the proboscis, the antennae plumose and about half as long as the proboscis. The lobes of the 9th tergite are very short, each of them bears about 8 hairs, the hairs about thrice as long as the lobes (fig. 2, *n*).

Larva.—Head round, not pigmented (fig. 6, *a*). Antenna one-fourth as long as the head; tuft represented by a small hair near the apex; tip with 3 small hairs and a blade. Anterior clypeal hair small and simple, lateral one 5-branched, two others bifid. Mentum (fig. 6, *b*) with 19 teeth, about equal in size, but the mid one larger, and the outer lateral pair smaller. Ventral hairs as in fig. 6, *a*. No conspicuous spines at the bases of the lateral thoracic hairs. On the thorax and the abdomen many stellate hairs; the tips of the branches of these hairs simple (not "fractured"). Comb on eighth segment without a chitinous base, consisting of 7–10 teeth without fringe (fig. 6, *c*). Siphon: (fig. 6, *d*) index 2.5. Pecten of two smooth teeth, the apical one about at the middle of the siphon; about 7 simple or bifid hairs on the ventral side, on the dorsal and lateral surfaces about 10 simple or bifid or trifid hairs. Anal segment: inner dorsal hair 4-branched, outer simple, both feathered. Lateral hair very large, about as long as the inner dorsal. Anal fan represented by a pair of 4-branched,

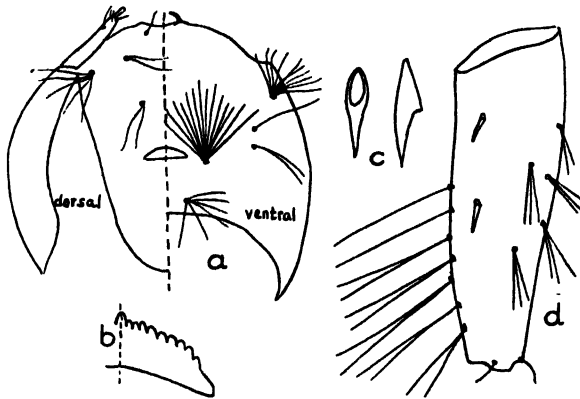


Fig. 6. *Tripteroides argenteiventris*, larva: *a*, head; *b*, mentum; *c*, comb tooth, front and side view; *d*, siphon.

slightly feathered hairs. Apical border of the segment with, on each side, some 7 spines, varying much in size, the longest half as long as the segment, and with denticles at their base.

Pupa.—Paddles rather narrow, twice as long as broad, the rib nearer the inner margin, border smooth; no apical hair. Eighth abdominal segment with a lateral 14–16-branched, slightly feathered hair, as long as the paddles, and an inner, very small, simple one.

***Uranotaenia diagonalis*, sp. n.**

♀. Head with flat, dusky grey scales and some upright forked ones; a pale margin towards the eyes. Tori and clypeus brownish. Palpi black, very short, exceeding the clypeus by not more than half its length. Proboscis black, shorter than the abdomen.

Mesonotal integument yellowish brown with brown scales, scutellum dark brown-scaled. Pleura pale yellowish, without scales, with a well marked, broad, dark brown line, beginning just under the anterior spiracle, obliquely crossing the upper part of the sternopleura, and the lower half of the mesepimeron and ending in the posterior lower edge of the latter. Wing: scales brown, no white markings; stem of the anterior

fork-cell almost thrice as long as the cell, that of the posterior 1.5 times as long; the base of the latter nearer the wing-base. Legs dark brown. Abdomen dorsally black, ventrally dark brown without any markings.

♂. Antennae plumose. Palpi and coloration as in the female. No special structures to the legs. Coxite with a tuft of strong hairs midway on the inner side, style very stout (fig. 7, *a*).

Larva.—Head (fig. 7, *b*) dark brown, round, antenna short and straight, antennal hair short, simple, near apex of antenna. Clypeal hairs short, simple; no specialised hairs on the clypeus; mentum: fig. 7, *c*. Comb on 8th segment consisting of 4–7 teeth in a row, the bases of the teeth fimbriated (fig. 7, *d*), a small trifid hair dorsally of the comb, a small 5-branched hair ventrally and a large 5-branched hair, about half as long as the siphon, towards the base of the siphon. Siphon brownish, index 2–2.5, nearly cylindrical but tapering a little towards the apex. Pecten of 3–7 teeth (fig. 7, *e*), last tooth beyond the middle of the siphon or before it. Siphonal tuft beyond the middle, moderately large, with 4–7 branches. Anal segment: dorsal hairs simple and plumose, lateral hair 4–6-branched, anal brush consisting of 3 very

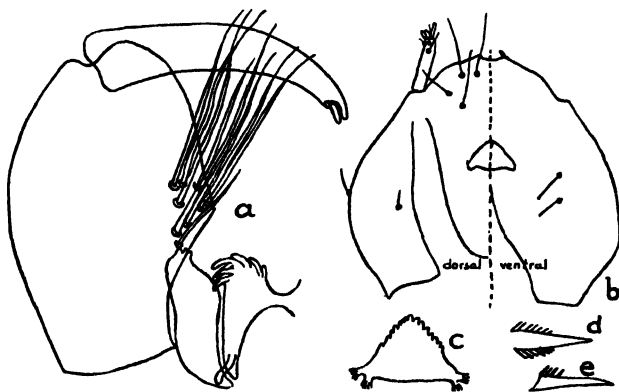


Fig. 7. *Uranotaenia diagonalis*: *a*, hypopygium; *b*, head of larva; *c*, mentum; *d*, tooth on 8th segment; *e*, tooth of pecten.

long simple plumose hairs, one bifid plumose hair somewhat shorter, and a short 4-branched hair on each side. Anal plate much broader than long. Gills cylindrical, apices rounded, dorsal pair a little shorter than the siphon, ventral pair two-thirds as long as the dorsal.

Habitat.—Many larvae were found in the axillae of the small leaves at the feet of the flowers of *Curcuma* sp. (Zingiberaceae). At the foot of each flower there was one small leaf that did not contain more than one ccm. of water. The larvae, if stranded on a moist surface, behaved quite differently from most other mosquito larvae in that case: they did not show the common aimless wriggling, but moved, seemingly intentionally, in one direction, somewhat like fly larvae, thus covering relatively great distances. It seems possible that in this way they may search for water, if their exceedingly small breeding-places are desiccated. The *Curcuma* was found in an open space in the virgin forest near Tanah Merah, Upper Digol River, New Guinea.

Description from 7 males, 7 females, 1 larval skin and 3 larvae.

The adult of this species can be easily recognised by the oblique dark brown stripe on its pleura.

Dr. Edwards informs me that some *Uranotaenia* specimens, collected at Rabaul, New Britain, by Mr. F. Taylor, are doubtless *U. diagonalis*.

***Aëdes (Aëdes) quadrifolium*, sp. n.**

♂. Head with dusky grey, flat scales. Tori blackish, very broad; second segment of antenna very broad, succeeding segments, except the last two, very short. Palpi dark brown, exceeding the clypeus by about its length. Proboscis 1.5 times as long as the fore femur, dark brown.

Mesonotum with dark brown scales. Scales on the upper part of the sternopleura and on the mesepimeron dark brown; behind the patch of scales on the upper anterior part of the mesepimeron there is a row of hairs continued as a patch of hairs on the lower half. Wing with dark brown scales; on the apical part the outstanding scales are ligulate, on the anterior fork-cell rather broadly so. Legs dark brown.

Abdomen dark brown, crumpled, ventral ornamentation invisible, if present. Hypopygium: style S-shaped, with 4 or 5 rather strong hairs on the inner border. Coxite with 4 leaf-like appendages near the apex, a small papilla with 2 hairs near the base, and a group of fine hairs still more basally on the inner side (fig. 8, a).

Habitat.—Torpedoboot River; one male specimen caught by Dr. Baardmans. Type in the British Museum.

From *Aëdes carmentis*, *A. similis*, and *A. funereus* this species can be distinguished by the rather broad scales on the anterior fork-cell. These scales are linear or at most ligular in the three species mentioned.

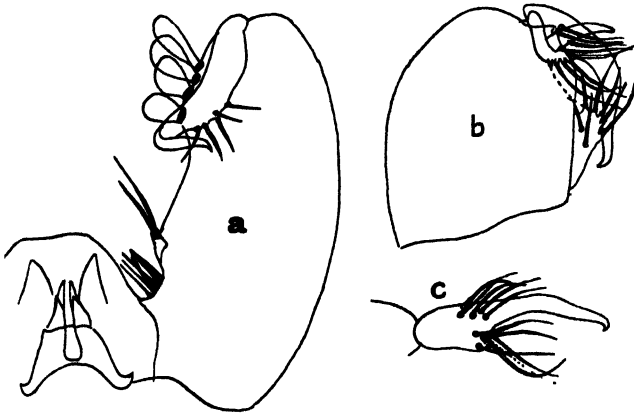


Fig. 8. *Aëdes (A.) quadrifolium*: a, hypopygium. *Aëdes (A.) ceramensis*: b, hypopygium; c, style of same.

***Aëdes (Aëdes) ceramensis*, sp. n.**

♂. In colour and ornamentation this species closely resembles *A. quadrifolium*, but there are no hairs on the mesepimeron and the outstanding wing scales are all narrow, almost linear. The tergites of the abdomen show very small, dirty white, basal, lateral patches. Hypopygium (fig. 8, b): basal lobe of the coxite with 7 pale hairs (drawn black in the figure in order the better to distinguish them from the hairs on the style). At the inner side of the apex of the coxite a stout spine, resembling that of *A. funereus*, but slightly bent. Style (fig. 8, c): basal third expanded on the inner side; an inner and an outer group of 5 hairs each on the apex of the thick part of the style.

Habitat.—Ceram (Moluccas); 2 males bred from larvae in Oewin and Warasiwa; Dr. Root sent to Dr. Edwards a drawing of the hypopygium of an *Aëdes* found in the Solomon Islands; the drawing resembles very much the hypopygium of *A. ceramensis*; probably it represents this species.

The species can be distinguished from *A. carmentis* by the smaller size of the lateral abdominal patches.

***Aedes (Finlaya) aureostriatus* (Doleschal, 1857).**

Males and larvae of this species, as understood by Edwards (Bull. Ent. Res., **14**, p. 382), were collected on the North Coast of Ceram. Comparison of both with Barraud's descriptions (Ind. J. Med. Res., **11**, pp. 849, 500) hardly left any doubt about its identity with *A. (F.) greeni* Theo. (1903), so that *greeni* must be considered as a synonym for *aureostriatus*.

***Aedes (Finlaya) niveus* var. *idjenensis*, nov.**

Very similar to the form *albolateralis* of *A. (F.) niveus*, but differing by having the pale lateral patches on the anterior part of the mesonotum pale golden instead of silvery white and by showing a patch of white, flat, broad scales on the posterior part of the posterior pronotal lobes; in the typical variety this structure is unscaled.

***Aedes (Finlaya) notoscriptus*, Skuse.**

Specimens bred from larvae found in a tree-hole in Merauke, New Guinea, differed from the classical descriptions in so far that there were three lines only on the mesonotum, the median straight one and the lateral curved ones. The short straight lines medially of the anterior part of the curved line and laterally of its posterior part were entirely absent. Examination of specimens in the British Museum proved that these short lines are very variable, either the anterior or the posterior pair often being absent.

The hypopygium of the Merauke specimens is depicted in fig. 9, *a-b*.

***Aedes (Finlaya) kochi*, Dön.**

The hypopygia of *A. (F.) kochi* and its allies, *A. (F.) kochi* var. *poicilia*, *A. (F.) kochi* var. *samoana* and *A. (F.) flavipennis*, are rather different. *A. kochi* and *samoana* are distinguished by a specialised hair on the medial side of the base of the coxite (side-piece) and by a blunt harpago; the latter is shorter and stouter in var.

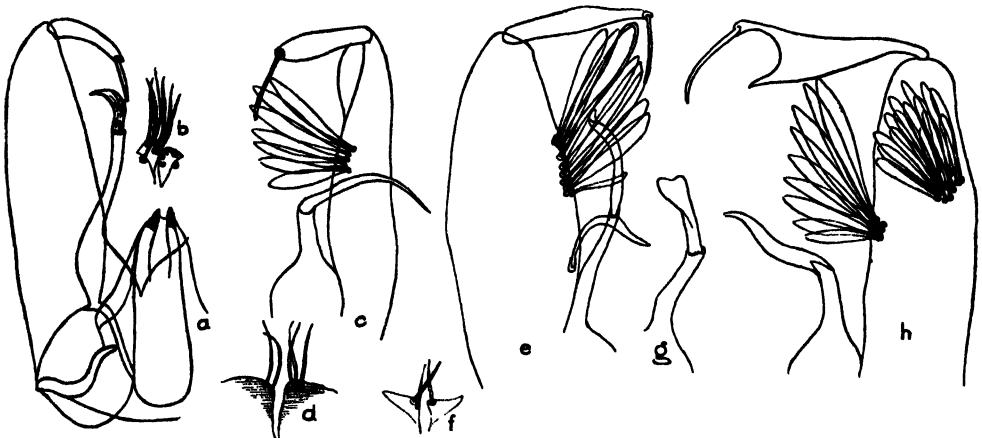


Fig. 9. Hypopygia of *Aedes (Finlaya)*.

- A. (F.) notoscriptus* : *a*, hypopygium ; *b*, lobes of 9th tergite.
A. (F.) kochi var. *poicilia* : *c*, coxite ; *d*, lobes of 9th tergite.
A. (F.) kochi : *e*, coxite ; *f*, lobes of 9th tergite.
A. (F.) kochi var. *samoana* : *g*, harpago.
A. (F.) flavipennis : *h*, coxite.

samaona. In *poicilia* the harpago has a sharp apex. In *flavipennis* the style (clasper) has a medial spinous process and there is an additional tuft of broad scales on the coxite, laterally and apically of the common one (fig. 9, c-h).

Aedes (*Skusea*) *tonsus*, Edw.

In the collection of the "Geneeskundig Laboratorium" in Batavia (Java) female specimens of *Skusea* from Celebes (W. coast: Mamodjoe and Sempaga) and Nias were found closely resembling and labelled as *Skusea amesi*. However, they did not show the patch of white scales on the upper half of the mesepimeron present in *S. amesi* and its allies, *S. fumidus* and *S. furvus* (vide Edwards, Bull. Ent. Res., 18, p. 274). Instead there were on the mesepimeron 2 or 3 rather strong bristles near the middle of the anterior margin. No other dark *Skusea* of this group present in the British Museum showed this structure. Unfortunately the unique type specimen of *S. tonsus* (from Amboina) is pinned through both the mesepimera, so that this character could not be investigated. Tentatively I might associate the Celebes females with the Ambon male.

Armigeres (*Armigeres*) *breinli*, Tayl.

By its scaled clypeus this species is closely allied to the Oriental *A. (A.) malayi*. The hypopygia are rather similar, but there are some differences in details. The style (clasper) of *breinli* is shorter, its teeth are less in number (9-11 as against 14-17)

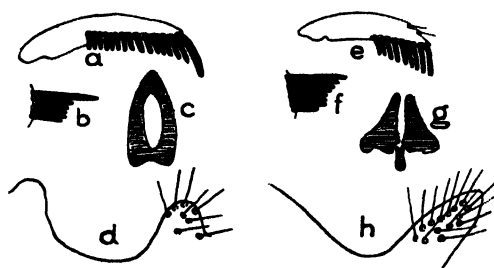


Fig. 10. Details of hypopygia: a-d, *Armigeres* (*Armigeres*) *malayi*; e-h, *A. (A.) breinli*; a, e, style; b, f, teeth on basal lobe of coxite; c, g, phallosome; d, h, lobes of 9th tergite.

and gradually decreasing in length from apex to base, whereas in *malayi* the apical tooth is distinguished by its greater size (fig. 10, a, e). A similar difference exists in the comb on the basal lobe of the coxite (side-piece), where the medial tooth exceeds the others far more in *malayi* than in *breinli* (fig. 10, b, f). The phallosome is triangular in *breinli* and ovate in *malayi*. The lobes of the ninth tergite in *breinli* are longer and more slender and bear more hairs (fig. 10, d, h).

Both sexes of *A. breinli* and *A. malayi* can be distinguished by the coloration of the venter. This is all white in *malayi*, in *breinli* mainly white but with narrow apical and basal black bands to the segments.

A. breinli was found in Fak-fak, Western New Guinea, breeding in a beached canoe, and in a coconut shell.

Culex (*Culex*) ? *siliens*, Wied.

Two males from Sorong (extreme West of New Guinea), caught by Dr. Soesilo, showed the following abnormal characters: Femora absolutely unspeckled, even the mid pair, which in typical *siliens* show the speckles best; bases of fork-cells of wings about level, or that of the anterior slightly nearer the wing-base; mesonotum with an indefinite pattern of pale golden and brown scales, but before the wing-base there

is an almost pure white patch, contrasting with the pale golden ornamentation of the rest; abdominal bands very narrow. Hypopygium as in *sitiens*.

Two females, caught at the same time in the same place, showed the same characters, only the base of the anterior fork-cell was definitely nearer the wing-base than that of the posterior. The females and the males were apparently conspecific.

In short these mosquitos had colorational characters much as in *vishnui*, and *sitiens* hypopygia. This observation recalls the case of *C. (C.) tritaeniorhynchus* var. *siamensis*, which has *tritaeniorhynchus*-colours and a *vishnui*-hypopygium. Apparently there are still mysteries in the systematical relationships of the species of the "*sitiens*-group."

***Culex (Culex) tritaeniorhynchus* var. *siamensis*, Barr.**

Hypopygia of male specimens, labelled "*tritaeniorhynchus*" from Sumatra (Mandailing Padang), Java (Batavia, Mt. Cornelis, Banbdoeng, Soerakarta, Soerabaja, Borneo (Boelongan), Tarakan (near Borneo), Celebes (Menado), Amboina, and Lombok (Mataram) were examined; all showed the *vishnui*-like structure characteristic of *C. tritaeniorhynchus* var. *siamensis* as described by Barraud (1931, Rec. Mal. Surv. Ind., 2, p. 283), and none that of typical *tritaeniorhynchus*. So far as the evidence goes, only the variety *siamensis* occurs in the Malay Archipelago.

***Culex (Culex) squamosus*, Tayl.**

Male and female specimens were collected in Amboina, Ceram, Halmaheira (Moluccas), Aroe Islands and on the Upper Digoel River (Southern New Guinea). They varied very much in the ornamentation of the mesonotum and the dorsum of the abdomen. The extreme variations of the mesonotum are: on the one hand, the anterior two-thirds wholly covered with pale golden scales, and on the other hand, the mesonotum almost completely covered with dark brown scales, pale scales only as a narrow, wavy, interrupted, transverse line before the level of the wing-bases. Transitional forms with various, more or less definite patterns often occur. At one end of the series of variations of the dorsal abdominal ornamentation are the specimens with well developed pale basal bands. In other specimens the bands are constricted in the middle or very narrow over their whole length; in still others they are interrupted in the middle, the interruptions growing larger and larger; and, finally, there are specimens with bands on the 5th or on the 5th and 6th segments only, or without any banding at all.

The sprinkling of the wings (on the costa, the first longitudinal vein and the stem of the fifth) was as a rule scanty; mostly the scales were of a dirty creamy colour; sometimes they were hard to detect or entirely absent. In most specimens there is an agglomeration of pale scales on the inner side of the costa near the wing-base.

Many female specimens showed a pair of tiny bare dots on the dorsum of each abdominal segment.

Larva.—The following description is from two larval skins.

Antenna about as long as the head, straight, slender, apical half pigmented; pre-apical bristles inserted near tip; tuft below the middle, with about 20 plumose branches; minute spicules on basal two-thirds of the antenna, a larger one just inside the insertion of the tuft (fig. 11, *b*). Mentum (fig. 11, *a*) triangular, with on each side 30–40 small lamelliform teeth, medially smallest. Clypeal hairs: A gone, B simple, C trifid, inserted obliquely behind B, B and C plumose, D minute, trifid. Eighth segment of abdomen with a patch of about 20 scales, fringed at their bases (fig. 11, *c*), a 4-branched and a 6-branched tuft, both feathered and a bifid hair between them. Siphon conical, index 8; pecten of 5–6 small, very transparent, hardly visible teeth, crowded near the base (fig. 11, *d*); tuft represented by a very minute bifid hair near

the middle. Anal segment : inner dorsal hairs 4-5-branched, outer simple, outer and inner not feathered. Plate as long as broad. Lateral hairs gone. Gills as long as anal plate (1.5 times as long in the other specimen), slender, conical, pointed, pigmented.

Pupa.—Medial half of the paddles pigmented. The paddles about round, their margin smooth ; a very minute apical hair. On the sides of the eighth abdominal segment a pair of small 5-branched feathered tufts (fig. 11, *e*).

Breeding-places : A slowly streaming rivulet, a swamp with brush wood in it, a canal.

The figure of the hypopygium of *C. squamosus* which I published in Bull. Ent. Res., 23, p. 82, does not show the most important characters well ; some details are now figured here (fig. 11, *f-h*).

The larva of this species has in common with *C. bitaeniorhynchus* the particular structure of the mentum and the almost invisible pecten, thus confirming Edwards'

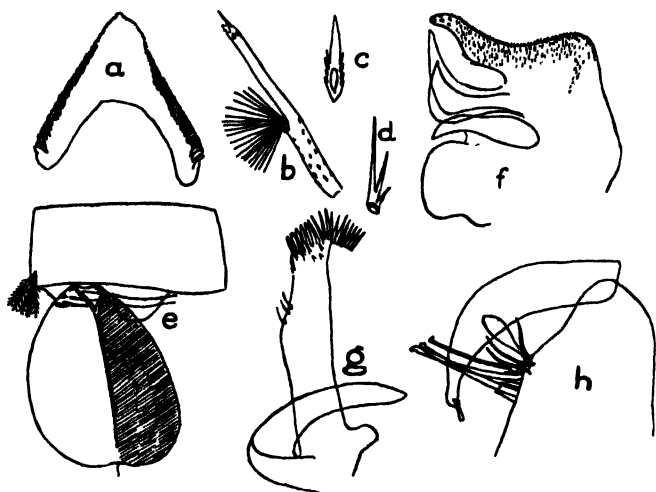


Fig. 11. *Culex squamosus*, *a-d*, larva ; *a*, mentum ; *b*, antenna ; *c*, comb tooth of 8th abdominal segment ; *d*, pecten tooth ; *e*, pupa, apex of abdomen ; *f-h*, hypopygium ; *f*, side view of mesosome ; *g*, anal segment ; *h*, apical part of coxite.

suggestion of its being closely allied to the latter species. The two species also agree in the extreme variability of the colour characters of the mesonotum and abdomen.

***Culex (Neoculex) crassistylus*, sp. n.**

♂. Head with narrow curved, creamy coloured scales and black forked ones ; laterally flat creamy scales extending medially as a border to the eyes, not reaching the vertex. Antennae densely plumose, plumes very long. Proboscis black, long and slender. Palpi black, exceeding the proboscis in length by more than $1\frac{1}{2}$ segments ; apical two segments densely hairy.

Mesonotal integument dark brown, with a pair of submedian paler lines, with dark brown, small, narrow curved scales. Scutellum denuded, integument of mid lobe dark brown, of lateral lobes paler. Pleurae without scales, integument brownish black ; lower mesepimeral bristle absent. Wings : subcosta, first longitudinal vein, forks of second and fourth and apical part of third with broad lanceolate scales ; veins otherwise poorly scaled ; anterior fork-cell 1.5 times as long as its stem, posterior just as long, bases level. Legs : coxae pale yellowish, inner sides of femora also, otherwise dark brown.

Abdomen : the tergites basally banded from the third segment, the bands pale creamy, otherwise dark brown. **Hypopygium :** style (clasper) club-shaped ; apical lobe of coxite (side-piece) branched, bearing three slender hairs, a small ovate leaf-like hair and two very strong hairs, one of which is S-shaped. Paraprocts with a comb of long blunt teeth. Phallosome simple (fig. 12, a).

Habitat.—One male specimen caught by the Medical Officer in Inawattan, New Guinea.

This species much resembles *Culex simplicicornis*, differing chiefly in the structure of the hypopygium. Moreover in *C. simplicicornis* the mesonotal scales and the mesonotal integument are less dark and the base of the anterior fork-cell is nearer the wing-base than that of the posterior.

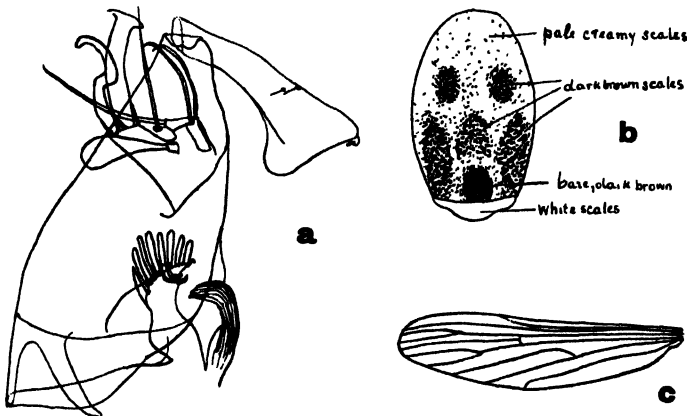


Fig. 12. *Culex (Neoculex) crassistylus*, sp. n. : a, hypopygium. *Culex (Culex) alis*, Theo., female : b, pattern of mesonotum, c, wing venation.

***Culex (Culex) alis*, Theo.**

Five male and five female adults were reared from larvae found in Western New Guinea (Fak-fak) and on the North Coast of Ceram (Sawaai and Horale Roemah Reat). Twice the larvae were found in beached canoes and once in a sago-tree-swamp. The mesonotum shows a pattern of pale cream-coloured and dark brown scales as depicted in fig. 12, b ; the scutellar scales are almost pure white. The wing venation (fig. 12, c) is rather characteristic, the anterior fork-cell being relatively short. In the males it is just as long as the posterior, in the females a little bit shorter. In both sexes the anterior fork-cell is as long as or a trifle longer than its stem, the posterior is about 1.3 times as long as its stem in the male, twice as long in the female. Its base is much nearer the wing-base, more so than in *Culex sitiens*.

Until now this species was known from Christmas Island only. It is the second species common to this island and the Australasian region, *Aedes (Stegomyia) variegata* being the other.

***Culex (Culicomyia) muticus*, Edw.**

♂. **Hypopygium :** the style (clasper) has a well developed crest on its apical part and a tuft of two rows of hairs on the outer side of its basal part. Near the apex of the crest there are two isolated hairs. The subapical adornment of the coxite (side-piece) consists of a group of 3 hairs ; a leaf-like hair and a very small hairy papilla apically, more towards the base a group of 2 hairs and more basally one isolated hair with a blunt tip (fig. 13, a). The mesosome has a slender, smooth, blunt-tipped, long projection and a short pointed one (fig. 13, b). The lateral arm of the anal segment is well developed and blunt (fig. 13, c).

Larva.—To Hill's description of the larva (Proc. Roy. Soc. Vict., **37**, p. 74) can be added that the pecten consists of 10 teeth, decreasing in size basally; there are two minute bifid hairs on the siphon (fig. 13, *d*).

This species is not rare in New Guinea and its neighbourhood. It has been reported by Edwards from New Britain, Merauke and Pionierbivak (New Guinea), and Amboina; by Hill from New Britain, New Ireland and the Solomon Islands. Moreover our collection contains specimens from Seleman, Karloetoe Kara and Hatoenoeroe (all on the North Coast of Ceram), from Halmaheira (Rodenwaldt), from Fak-fak (Leimena) and Albatrosbivak (Wirth), both in New Guinea. Hill mentions a horse-trough as a breeding-place. We bred adults from larvae found in a beached canoe, in a pool in the forest, in a pool in the jungle, and in a tree-hole.

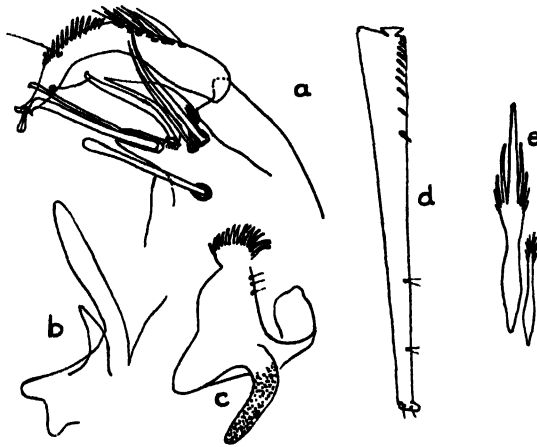


Fig. 13. *Culex (Culiciomyia) muticus*: *a*, style and tip of coxite; *b*, mesosome; *c*, anal segment; *d*, siphon of larva. *Orthopodomyia anopheloides* var. *andamanensis*: *e*, a large and small comb tooth of larva.

***Orthopodomyia anopheloides* var. *andamanensis*, Brug.**

Larva.—Many larvae were found in a buttress-root hole in Karloetoe Kara (Ceram) and male as well as female adults were reared from them.

The head is all brown and round. Antenna: shaft 7 times as long as broad, half as long as the head, all dark brown; antennal tuft 4–5-branched, feathered, implanted a little beyond the basal fifth; tip with 2 large and one small spinose hair. Clypeal hairs long, 5–7-branched, feathered. Occipital hairs rather long, bifid or bifurcate. The main tracheal tubes show a conspicuous spindle-shaped enlargement in meta-thorax, mesothorax and first abdominal segment. Seventh abdominal segment brown on upper and lateral surface, yellow ventrally. Eighth segment with the basal two-thirds brown over almost the whole circumference, apically yellow. Comb teeth implanted just beyond the brown portion. One row of 11–14 large teeth, each of them alternating with 1 or 2 or 3 small ones; at the ventral end of the comb there is an uninterrupted group of 4 or 5 small teeth. Central projection of the large teeth distinctly longer and stouter than the others (fig. 13, *e*). At the apical side of the comb two simple hairs and one 12-branched feathered tuft between them; a small 4-branched feathered hair ventrally of the comb. Siphon: index 7–8, slightly tapering, straight bordered; at the base not quite twice as broad as at the apex. A paired ventral tuft of 10 feathered branches, longer than the siphon's breadth, implanted a little bit beyond one-fourth of the length. Anal segment with a large brown plate all round apically, and a narrow brown strip basally. Inner dorsal hair smooth, 9-branched, one branch distinctly longer than the others; outer dorsal

hair simple ; lateral hair small, bifid or trifid. Anal fan consisting of 9-14 tufts. Dorsal gills about as long as the anal segment, ventral ones two-thirds as long.

The larva differs from that of typical *O. anopheloides* by the smaller number of branches of the antennal tuft (6-8 in *anopheloides*), the greater number of large comb teeth (7-10 in *anopheloides*), the greater siphonic index (5 in *anopheloides*) and the tuft of the siphon being implanted nearer the base (in the middle in *anopheloides*).

Some larvae and adults collected by Dr. Given in Singapore and at present in the British Museum apparently belong to this variety.

Pupa.—Paddles oblong, not quite twice as long as the eighth abdominal segment, smooth bordered, without an apical hair. Eighth abdominal segment with a 11-14-branched feathered hair at the lateral apical angle, this hair about as long as the segment ; inside it a simple smooth somewhat shorter hair. Trumpets triangular.

THE DEVELOPMENTAL STAGES OF *BRACON TACHARDIAE*, CAM. (HYM.).

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and Orissa, India.*

1. Introduction.

Bracon tachardiae is an ectoparasite of the larva of *Eublemma amabilis*, Moore (NOCTUIDAE), which is a predator of major importance on lac, *Laccifer lacca*, Kerr (COCCIDAE).

The bionomics and life-history of this Braconid are being published in a separate paper.

I am indebted to Mrs. Dorothy Norris, Director of the Indian Lac Research Institute, to Dr. C. F. C. Beeson, Forest Entomologist, and to Mr. J. C. M. Gardner, Systematic Entomologist, Forest Research Institute, Dehra Dun, for criticism and advice, and to Mr. E. Heber, Artist and Photographer at this Institute, for the preparation of the figures.

Some of the measurements used in working out averages have been taken from Department routine cage-slips and I should like to acknowledge the work of the Assistants and Fieldmen who have made these measurements. The terminology employed in describing and figuring the larval head and mouth-parts is so far as possible that of Vance & Smith (1923), that employed in figuring external structures of the adult is similar to that used by Salt (1931). Four figure logarithms were used in making calculations.

Specimens of the species here dealt with were submitted in 1927 to the Imperial Bureau of Entomology and were identified by Mr. D. S. Wilkinson as *Bracon tachardiae*, Cam.

2. Description of the Developmental Stages.

The Egg (fig. 1, a, b).

The egg is circular in cross section and slightly curved; the colour at oviposition is translucent white, except for a small area at the caudal end into which the egg contents do not extend and which is in consequence transparent. The chorion is smooth and shining. The cephalic end is bluntly rounded, and from it the egg broadens, the broadest region being the cephalic two-thirds of the length, from this point the egg gradually tapers to the caudal end, which is narrowly rounded. Some of the eggs examined showed a distinct bulb-like expansion in the caudal third (fig. 1, a). The average length is 0.83 mm., the maximum and minimum records being 1.02 and 0.59 mm. respectively in 100 eggs; the average breadth was 0.15 mm., with a maximum and minimum of 0.2 and 0.15 mm.

The developing embryo can be seen within the egg surrounded by the embryonic membranes; prior to hatching it appears to swallow the amniotic fluid and air enters the tracheae. The embryonic membranes remain behind when hatching occurs.

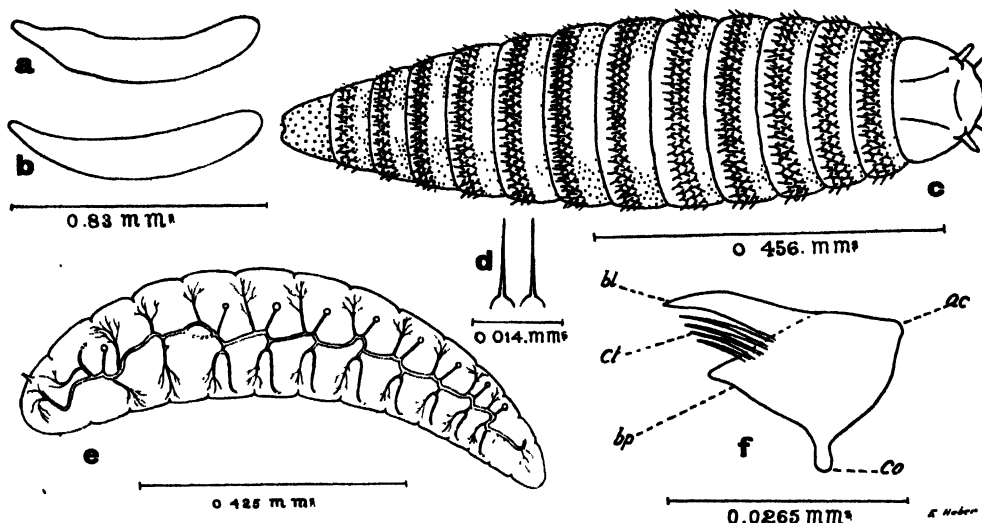


Fig. 1. *Bracon tachardiae*, Cam.: a, b, egg just laid; c, 1st instar larva, dorsal view; d, spines enlarged; e, 1st instar larva, tracheal system, lateral view, semi-diagrammatic; f, mandible of 1st instar larva, ventral; ac, acron; bl, blade; bp, basal piece; co, condyle; ct, comb-like teeth.

The First Instar Larva (fig. 1, c).

Length				Breadth			
Max.	Min.	Av.	No.	Max.	Min.	Av.	No.
0.82	0.56	0.69	Soon after hatching. 30	0.25	0.13	0.17	30
0.96	0.73	0.83	After feeding for some time. 30	0.28	0.16	0.2	30
0.96	0.56	0.76	Total range. 60	0.28	0.13	0.19	60

The larva, almost as soon as the head and anterior segments have emerged from the egg, attaches itself by its mouth-parts to the body of the host larva and starts to feed by suction. On hatching it measures just over 0.5 mm. in length. The empty egg-shell may remain attached to the posterior segments of the larva until the first moult occurs; more usually it is shed. The larva may remain at the original point of attachment for the whole instar; more usually, however, it feeds for some time, and then migrates to a new place. Its usual position is lying on the body of the host; larvae are sometimes observed with their mouth-parts attached to the host, and with their bodies at right angles to the host undulating as imbibition occurs.

The head-breadths of 20 larvae just after hatching averaged 0.13 mm., with a maximum and minimum of 0.14 and 0.11; after feeding for some time the head-breadths of 30 larvae averaged 0.14 mm., with a maximum and minimum of 0.16 and 0.12. It may be safely stated that head-width does not increase appreciably during the instar. The average width for the instar as a whole is 0.14 mm.

The 1st instar larva has a well differentiated head, three thoracic and ten abdominal segments (fig. 1, c). The cuticle is shining; the colour on hatching translucent white. The greatest breadth is in the vicinity of the first three abdominal segments, from which region the body tapers towards the posterior end. After feeding the thoracic and anterior abdominal segments take on a faint greenish-yellow tinge, due to the colour of the ingested food. Urate granules are present, but small.

The head bears a pair of prominent finger-like antennae (fig. 2) placed on slight elevations in the dorso-lateral region; average length 0.025 mm., the average breadths at base and apex 0.0095 and 0.005 mm. respectively. The disposition of the setae on the head is shown in fig. 2.

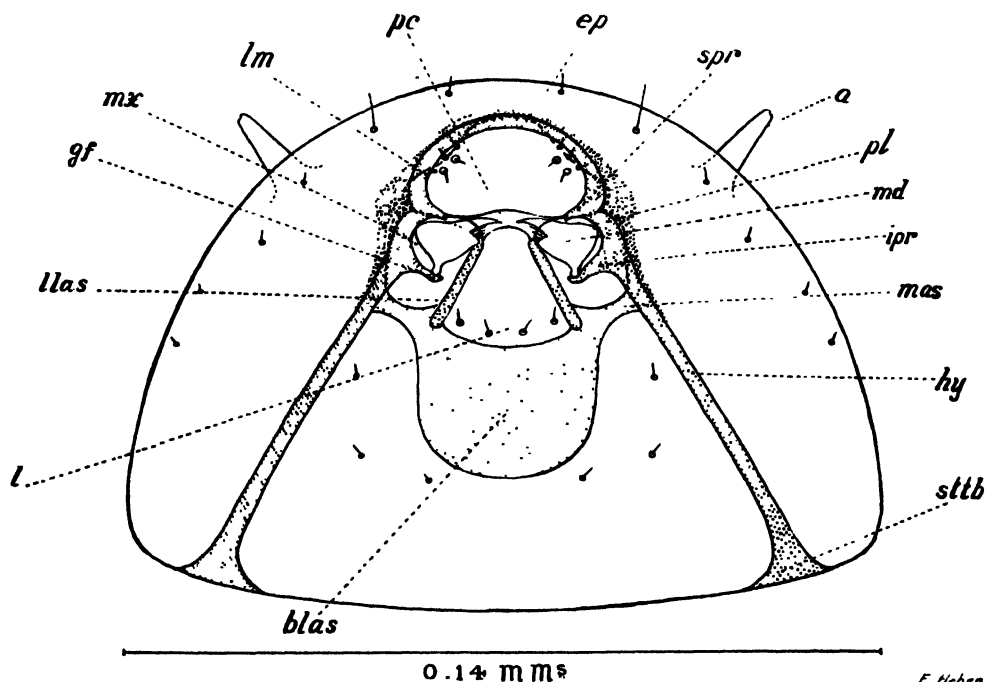


Fig. 2. *B. tachardiae*, head and mouth-parts of 1st instar larva, ventral view, somewhat diagrammatic, the maxillae being shown as if transparent; *a*, antenna; *blas*, basal labio-stipital sclerite; *ep*, epistoma; *gf*, glenoid fossa; *hy*, hypostoma; *ipr*, inferior pleurostomal ramus; *l*, ligular region; *llas*, lateral labio-stipital sclerite; *lm*, labrum; *mas*, maxillary sclerite; *md*, mandible; *mx*, maxilla; *pc*, preoral cavity; *pl*, pleurostoma; *spr*, superior pleurostomal ramus; *sttb*, spur of transverse tentorial bar.

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The mouth-parts (fig. 2) consist of a labrum, maxillae and ligular area which border the preoral cavity, and the mandibles. The labrum is faintly bilobed and bears two large and three small pairs of setae; it defines the anterior border of the preoral cavity. The ligular area, which bears four setae, defines the posterior border; the lateral borders are defined by the maxillae, each of which bears two setae. Maxillary and labial palpi are absent. The mandibles (fig. 1, f) lie below the maxillae and are well chitinised and pigmented; the basal portion is thickened, and posteriorly bears a condyle which articulates with the glenoid fossa of the inferior pleurostomal ramus; anteriorly the acron articulates against the superior pleurostomal ramus. Centrally the basal piece projects bluntly into the preoral cavity, average length 0.022 mm., the breadth of the mandible from acron to condyle averaging 0.018 mm. The blade of the mandible, measured from acron to apex of blade, averages

0.0265 mm., projecting into the preoral cavity and meeting that of the mandible of the other side. The blade bears in addition apparently four fine slightly curved comb-like teeth. A small spur on the posterior extremity of the hypostoma represents the rudimentary transverse tentorial bar.

The body segments (fig. 1, *c*), except the ultimate abdominal, are encircled dorsally and laterally by posteriorly directed stout spines placed roughly in three rows, the spines in each row being approximately alternate with those of the neighbouring row. The spines (fig. 1, *d*) are 0.012 mm. long and are placed very close together; under low powers they appear to form a single row only. The spines weaken in the ventro-lateral region and do not extend on to the ventral surface, which is naked. The rows of spines are approximately equidistant from the anterior and posterior borders except on abdominal segments 3-9, where they are somewhat closer to the posterior border. The spines are weaker and less numerous on the 9th abdominal segment. They are probably of use to the larva while hatching and wriggling to the host, particularly where the egg is not laid actually on the host's body.

The dorso-lateral, lateral, and ventro-lateral regions of each segment are provided with a number of very small setae, anterior to the rings of spines. Their extent is greater in the more posterior segments; on the 9th abdominal segment they extend well into the dorsal region, and on the 10th they completely cover the whole dorsum. They do not extend on to the ventral surface.

✓ Open spiracles occur on the prothorax and first eight abdominal segments. The tracheal system (fig. 1, *e*) consists of a pair of lateral longitudinal trunks connected by anterior and posterior commissures in the prothorax and 9th abdominal segments. The main lateral trunk runs into the head, where it ramifies to supply the anterior and ventral regions. The anterior commissure gives off a branch on each side, which supplies the posterior and dorsal regions of the head. There are 10 pairs of ventral and 10 pairs of dorsal trunks, which arise from the main lateral trunk. No dorsal trunk arises in the prothorax; in the remaining segments except the 9th and 10th abdominal the dorsal trunks originate close to the anterior border of the segment and are pre-spiracular, passing superficially to the dorsal region, where they branch profusely to supply the anterior region of their segment of origin and the posterior region of the preceding segment.

The ventral trunks arise from the main lateral trunk in the anterior half of the segment and are post-spiracular. No ventral trunk occurs in the mesothorax or abdominal segments 9 and 10. The prothoracic ventral trunk arises close to the posterior border of the segment and supplies the posterior region of the prothorax and anterior region of the mesothorax. The metathoracic trunk supplies the anterior region of that segment and the posterior region of the mesothorax. The ventral trunks in abdominal segments 1-8 are double; the anterior branch supplies the anterior region of its segment of origin and the posterior region of the preceding segment; the posterior runs ventrally without dividing to join with the corresponding branch of the opposite side, ventral commissures being thus formed in abdominal segments 1-8. The lateral trunks in the 9th abdominal segment give off a few small tracheoles, but no trunks. The posterior commissure gives off two small tracheoles on either side to the 10th abdominal segment. No accessory lateral commissures occur; in one case a small commissure was observed in the metathoracic, 1st abdominal region, and was probably an abnormality (fig. 1, *e*).

At the first moult the head-capsule ruptures dorsally along two lateral longitudinal lines running from the posterior border of the head to the region of the antennae, thus forming a flap hinged on a lateral line close to the origin of the antennae; the flap, therefore, does not bear the antennae. The body skin splits dorsally, the split extending into the metathorax. The exuviae are passed backwards by wriggling, the old head-capsule being ventral in position, and are finally shed altogether, being left lying closely adpressed to the body of the host larva.

The Second Instar Larva.

The larva of this stage is about 1 mm. in length and about 0.3 mm. in breadth. It feeds lying on the surface of its host, and may take up the perpendicular position which is sometimes assumed by the larva of the 1st instar, which it resembles in general shape.

The average head-width is 0.18 mm. The head is clearly differentiated, translucent white; the cuticle is shining, smooth and devoid of spines; the prothorax and 9th and 10th abdominal segments are translucent white, the remaining segments showing a faint olive-green tinge due to the colour of the contents of the alimentary canal. Urate granules are visible sparsely scattered over the meso- and metathorax and the anterior abdominal segments. The tracheal system is in essentials similar to that of the 1st instar larva.

The antennae are more squat than in the 1st instar, and average 0.024 mm. in length, being 0.018 mm. broad at the base, and 0.005 mm. at the apex. The mouth-parts are in all essentials similar to those of the 1st instar larva. The transverse tentorial bar is represented by a small strut at the posterior extremity of the hypostoma, joined to its fellow of the opposite side by a fine faintly-staining bar. The mandible averages 0.0341 mm. from acron to apex of blade and is similar to that of the previous instar, except that the basal piece does not project to such an extent into the pre-oral cavity. The blade is provided with five fine slightly curved comb-like teeth.

Setae occur irregularly on all the body segments; abdominal segments 1-8 with 5-7 pairs, 9 and 10 with usually 4 pairs, the thoracic segments with mainly unpaired setae, the number being irregular, though usually about 10-12.

Areas of peculiar cuticular prominences (fig. 4, c), similar to those described by Salt (1931) in *Pimpla detrita*, Holmgr., occur on the thoracic and abdominal segments except the prothorax. The prominences take the form of transversely elongate elevated papillae, whose crests bear minute teeth; they are placed in transverse rows, towards the anterior borders of the segments; on the posterior segments their extent is greater.

The second ecdysis occurs in a similar manner to the first. The head-capsule, however, ruptures along two lateral longitudinal lines, thus forming three flaps, the median one bearing the antennae. The rupture of the skin extends usually to about the region of the 1st abdominal spiracle, although in some cases it does not extend quite so far and in others it may extend into the 2nd abdominal segment.

The Third Instar Larva.

The larva of this instar is about 1.5 mm. long and 0.45 mm. broad, and feeds lying on the body of the host, or lying curved over it.

The average head-width is 0.22 mm. The larva is considerably stouter than that of the previous instar, the head is clearly differentiated, but less prominent. The cuticle is colourless, devoid of spines and glabrous. The head, prothorax and 10th abdominal segment are translucent white, the remaining segments showing a creamy yellow or pink tinge due to the ingested food. Urate granules are visible and fairly large. Head and prothorax narrow, mesothorax broader, metathorax and 1st-8th abdominal segments broader (about equal in breadth), 9th and 10th abdominal segments narrower.

The tracheal system does not differ in any essential from that of the larva of the preceding instar.

The antennae are about the same length as those of the previous two larval stages, 0.024 mm.; they are much broader basally, the basal breadth being 0.022 mm., the apical 0.005 mm. The mouth-parts are essentially similar to those of the previous

instar. The mandible is also similar; average length of acron to blade apex 0.0405 mm.; there are five comb-like teeth. The transverse tentorial bar is similar to that in the 3rd instar, the struts being, however, more prominent.

Setae occur on all the body segments irregularly placed in the median line. Cuticular prominences occur on all the body segments except the prothorax, their disposition being as in the 2nd instar larva.

The method of rupture of the head capsule and of the body segments in the 3rd moult is essentially the same as in the second moult. The rupture of the cuticle extends to the 1st or 2nd abdominal segment.

The Fourth Instar Larva.

The larva feeds lying on, or more often lying curved over, the body of its host. The length is approximately 2 mm. and the breadth just over 0.5 mm.

The average head-width is 0.27 mm. The 4th instar larva is very similar in general shape to the third, but is considerably larger. Urate granules are much more prominent. The cuticle is smooth, devoid of spines, the shining appearance being very noticeable. The alimentary canal contents give the body segments a creamy yellow, greenish, or pinkish colour, depending on the host and its condition. The tracheal system is similar in all essentials to that of the previous instar.

The antennae are more squat than in the 3rd instar, being about as broad at the base as they are long, 0.025 mm., the apical breadth being 0.0075 mm. The mouth-parts are similar to those of the third instar larva in all essentials, the average length of the mandibles from acron to blade apex being 0.0489 mm., and the comb-like teeth five in number. The transverse tentorial bar runs internally across the head, connecting at each side with the posterior ends of the hypostoma; the central region of the bar stains more lightly than the lateral regions.

Setae occur on all the body segments, being placed transversely in the median region, and number about 10. Cuticular prominences as in the two previous instars occur on all the thoracic and abdominal segments except the prothorax, disposed as in the previous instar.

The fourth ecdysis occurs in an exactly similar manner to the third.

The Fifth Instar Larva.

The fifth instar larva in general is between 3 and 4 mm. in length (max. 4.25, min. 2.0) and about 1 mm. broad (max. 1.38, min. 0.7). The minimum measurements were observed in exceptionally small larvae. In general, larvae which approach the maximum of the range are females, while those that approach the minimum are males.

The average head-width is 0.33 mm. The head is clearly defined, small, longer than broad (viewed anteriorly), the greatest breadth in the dorsal third, the narrowest at a point two-thirds from the vertex, below which it expands again slightly. The mandibles and scleromes of the mouth-parts are brown and prominent.

Greatest breadth in the region of the 4th-6th abdominal segments, 7th, 8th and 9th tapering, 10th small, translucent, colourless, shaped like a truncated cone. Cuticle colourless, the alimentary canal contents giving the larva a creamy white, yellowish, or pink tinge, according to the host larva and its condition. A lateral longitudinal keel-like ridge occurs on abdominal segments 1-8 just ventral to the spiracles, becoming extremely prominent as the respiratory contractions of the larva take place. Transverse ridges occur on the dorsa of abdominal segments 1-6, towards the anterior border, being most prominent on segments 2-5.

The antennae (fig. 3, *a*) average 0.23 mm. in length and are narrow and finger-like, basal and apical breadths 0.011 mm. and 0.006 mm., set in elliptical foramina (fig. 3, *af*), 0.05 mm. long by 0.036 mm. broad.

The mouth-parts and head scleromes are shown in fig. 3. The labrum forming the dorsal border of the pre-oral cavity is slightly bilobed and overlies the pleurostoma and the greater portion of the mandibles, bearing two large and three small setae on each side. The maxillae are divided into cardo and stipes by the stipital sclerome the former bearing a single seta, the latter three setae, and a single-jointed palpus; the internal border of the maxilla forms a finger-like projection into the pre-oral cavity. The ligular area bears 4 setae and a pair of single-jointed palpi, the ligular sclerome being rather unusual in shape. The frontal suture is markedly obtuse-angled. The arrangement of the facial setae is shown in the figure. The mandibles

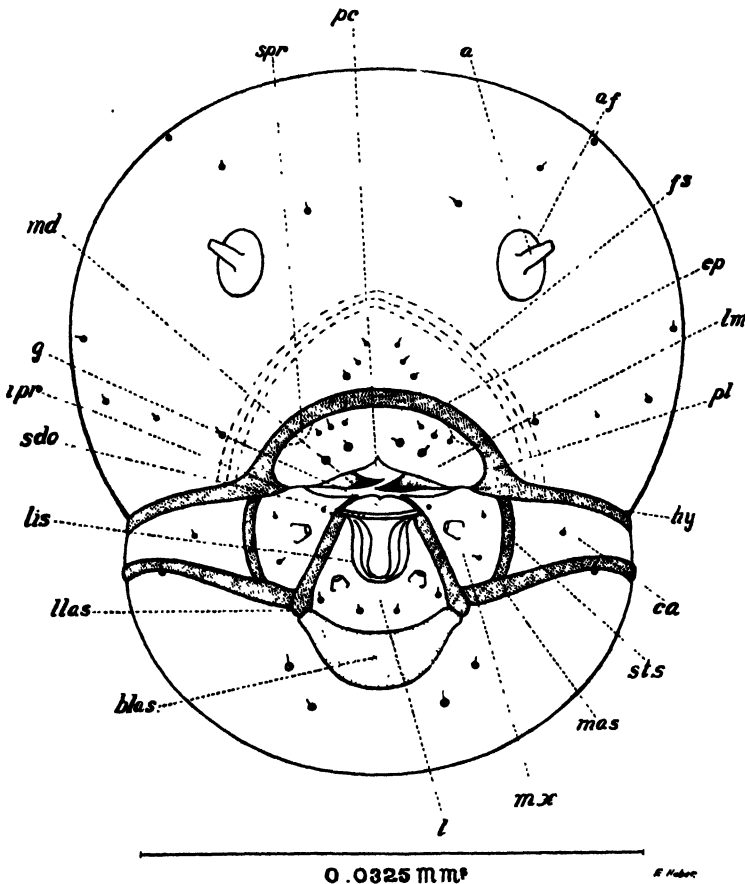


Fig. 3. *B. tachardiae*, head and mouth-parts of 5th instar larva, anterior view: *af*, antennal foramen; *ca*, maxillary cardo; *fs*, frontal suture; *g*, glossa; *lis*, ligular sclerome; *sdo*, orifice of silk duct; *sts*, stipital sclerome; other lettering as in fig. 2.

(fig. 4, *b*) in dorsal view are similar to those of previous instars, and average 0.0604 mm. in length. They bear 6-7 faintly curved, pointed comb-like teeth, of which in the majority of preparations only 5 are distinguishable, that closest to the blade having been observed once only; the most remote from the blade is small and may not always be apparent. The mandibles articulate with the superior pleurostomal ramus and the glenoid surface of the inferior pleurostomal ramus. The tentorium is represented by the transverse tentorial bar which crosses the head internally, running from the posterior extremity of the hypostoma of one side to a similar position on the other side.

The tracheal system (fig. 4, *a*) is in all essentials similar to that of the larva of the 1st instar; the dorsal and ventral trunks branch more profusely, and a number of tracheoles arise from the main trunks.

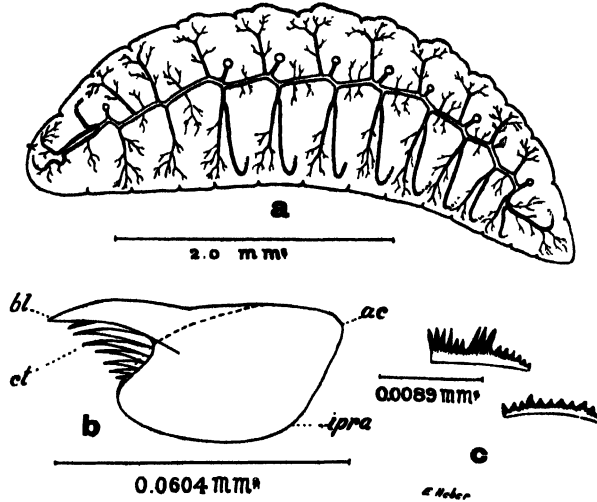


Fig. 4. *B. tachardiae*: *a*, 5th instar larva, tracheal system, lateral view, semi-diagrammatic; *b*, 5th instar larva, mandible, dorsal view; *c*, cuticular prominences in 2nd instar larva; *ac*, acron; *bl*, blade; *ct*, comb-like teeth; *ipra*, point of articulation with the inferior pleurostomal ramus.

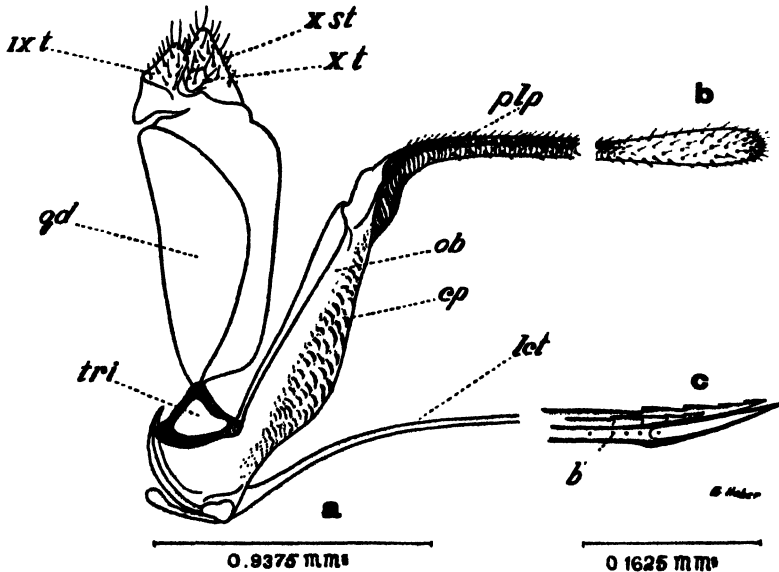


Fig. 5. *B. tachardiae*: *a*, ovipositor and parts of female adult, lateral view; *b*, apex of palpus to same scale, lateral; *c*, apex of ovipositor enlarged to show sheath and stylets, lateral; *b*, pores; *cp*, cuticular prominences; *lct*, lancet; *ob*, oblong plate; *plp*, palpus; *qd*, quadrate plate; *tri*, triangular plate; *IXt*, ninth tergite; *Xt*, tenth tergite; *Xst*, tenth sternite.

The cuticle of the thorax and abdomen under the binocular, appears to be shagreened, particularly in the thoracic region, owing to a dense covering of short, closely placed, posteriorly directed spines. These spines are absent from the greater part of

the head, the 10th segment and the intersegmental areas; the extent of the intersegmental naked areas is greater on the more posterior segments. A small transverse area of these spines occurs on the ventral surface of the head close to the posterior border, which is not visible in anterior view. The spines are 0.012 mm. in length and lie closely adpressed to the body. They are probably of value in that they afford purchase to the larva while moving and particularly when spinning the cocoon. On all the body segments including the 10th abdominal there occur sparse irregularly placed setae, whose length averages 0.03 mm. Cuticular prominences occur on the 8th, 9th and 10th abdominal segments only, but are not very numerous on the 8th and 9th. It is interesting to note that prominences of an exactly similar type are found on the lateral region of the terminal abdominal segments of the male imago; on the oblong plate of the external genitalia of adult female prominences of a very similar type also occur (fig 5, a).

The fifth moult differs from the previous ones, in that the head-capsule splits longitudinally in the median line and the two halves so formed split away from the epistoma, thus forming two lateral flaps which bear the antennae. In the case of

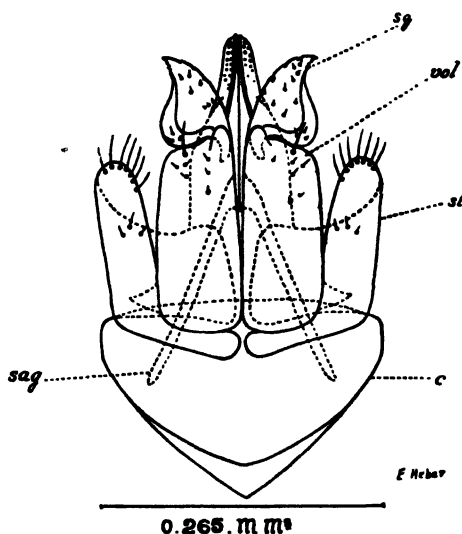


Fig. 6. *B. tachardiae*, genitalia of male adult, ventral view: *c*, cardo; *sag*, sagitta; *sq*, squama; *st*, stipes; *vol*, volsella.

male pupae the 5th exuviae may be shed completely, but are usually found adhering to the terminal region of the abdomen. In the case of female pupae the 5th exuviae are found with the anterior half enclosing the terminal region of the ovipositor, the head-capsule being dorsal in position.

The Cocoon.

In general cocoons measure between 3 and 4.5 mm. in length (max. 5.0, min. 2.6) and between 1 and 2 mm. in breadth, those towards the maximum of the range being constructed by larvae which will give rise to females and those towards the minimum by male larvae. The texture of the cocoon is thick, consisting of whitish silken threads and translucent; the surface has a matt appearance and there are very few loose threads. No cap is formed, but eclosion occurs through a circular hole with serrated edges, which is bitten by the adult about to emerge in the antero-dorsal or lateral region of the cocoon. The ventral surface is flattened, the dorsal arched and angled to the ventral, the anterior and posterior ends being rounded. Surfaces in

contact with other surfaces or cocoons are flattened. Cocoons are found in lac at the side of or below the host's remains.

Larvae require some support to construct cocoons, and if kept separately in plain concave glass blocks frequently fail to do so; if other larvae or host remains are present, construction is facilitated. Under natural conditions the gallery of the host larva provides adequate support. Génieys (1925) referring to *Habrobracon brevicornis*, Wesm., observed that larvae kept in glass dishes or boxes failed to spin and attributed it to excess of humidity. He introduced a piece of cardboard or pith to dry the atmosphere and a cocoon was constructed; it seems possible that the primary function of the cardboard may have been the purely mechanical one of support.

Shortly after completing the cocoon the larva starts to pass the meconium. At this stage the thoracic segments are markedly swollen, and the abdominal segments distended, the longitudinal and transverse ridge becoming prominent. The meconium consists of a series of small oval granules, which may remain separate or are

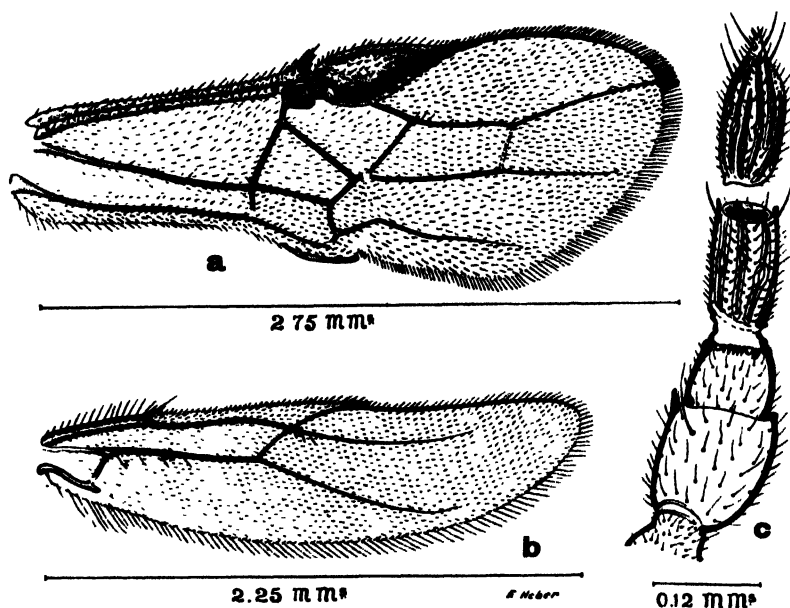


Fig. 7. *B. tachardiae*: a, right forewing of adult female; b, right hind wing of adult female; c, scape, 1st and apical antennal joints of adult female.

more usually massed together, and varies considerably in colour, being light brown, dark brown, black, grey, greenish or reddish; it is passed within the cocoon and lies in a compact mass at the posterior end.

The larva after passing the excreta becomes inactive and enters the prepupal stage. The thoracic segments are noticeably swollen, the greatest breadth being in region of the middle of the abdomen, which, however, has decreased in size owing to the extrusion of the excreta; the cuticle of the abdominal segments, except the 10th, is thrown into a large number of fine short longitudinal wrinkles. In the early prepupa the lateral keels are still discernible, though they are not prominent, and the dorsal ridges can still be seen on the 3rd, 4th and 5th abdominal segments. As the prepupal stage advances, the eye-spots, which are originally yellow and later brown, appear in the dorso-lateral region of the prothoracic segment, enclosing the prothoracic spiracle.

The Prepupa.

In the late prepupa, the drawing away of the cephalic organs of the larva from within the exoskeleton of the head leaves the latter more transparent. The thorax is noticeably swollen and the wings and appendages can be distinguished lying below the larval cuticle, and in the case of female prepupae the ovipositor can be distinguished beneath the larval cuticle in the abdominal region.

The Pupa.

The pupa is of the exarate type common to the Hymenoptera and is free within the cocoon. In general, male pupae are between 2 and 3 mm. in length and about 1 mm. in breadth, while female pupae are between 2.5 and 3.5 mm. in length and between 1 and 1.5 mm. in breadth.

The pupa is at first translucent white; the eyes are originally white, deepening in colour more rapidly in the anterior region and passing through very pale yellow, yellow brown, brown, deep chocolate-red, deep crimson, to black. The ocelli, also originally white, pass through similar stages though rather more slowly. The head and thorax change through pale yellow and light brown to the adult rufo-testaceous coloration. The wing-sheaths take on a grey tinge at first distally, then proximally and finally turn black, more rapidly in the posterior region. The antennae pass from white, *via* yellow and grey, to the final black colour, and the legs take on a brown coloration. The abdomen, at first creamy white with the urate granules clearly visible, deepens to light yellow, yellow, and finally yellow-brown.

In the case of the female a median area on the 3rd and 4th dorsal abdominal segments develops a dark colour, which may extend to the anterior region of the 5th dorsal segment. In the male the 3rd to the 6th dorsal abdominal segments develop dark-coloured areas. In adult life the extent and depth of these areas increases.

3. Possibility of two Series of Larvae occurring.

In view of the difference in size of male and female pupae, and the consequent possibility of two series of larvae, one male and one female, occurring, one hundred adults of each sex were selected at random from material preserved during the last few years, and their lengths measured under a binocular microscope. The following results were obtained.

Length of Imagines.

Male				Female			
Max.	Min.	Av.	No.	Max.	Min.	Av.	No.
4.0	1.75	2.88	100	4.5	2.0	3.34	100

It is clear that, while the actual range of size of the sexes is very similar, the males are on the average smaller than the females. It is probable, therefore, that two series of larvae do occur, which, however, overlap very considerably, and it is only towards the maximum and minimum of the range that larvae are of one sex only.

In the case of head-width and mandibular length the difference between the maximum and minimum for each instar does not increase appreciably except between the 4th and 5th instars; even here the increase is not considerable. It would appear that growth of the head-capsule is probably independent of increase in body size and of sex (*cf.* also p. 538).

TABLE I.
An Analysis of the Head Measurements of the Larvae of B. tachardiae in each Instar.

Instar	No.	Head width observed			Calculated width	Difference in average observed and average calculated width	Standard deviation	Probable error in average	Coefficient of variation
		Max.	Min.	Average					
1st	50	0.1600	0.1225	0.1364 (0.14)	—	—	0.0102	±0.00098	7.513
2nd	30	0.2000	0.1625	0.1811 (0.18)	$0.1364 \times 1.25 = 0.1705$ (0.17)	0.0106	0.0107	±0.00132	5.923
3rd	30	0.2449	0.2000	0.2212 (0.22)	$0.1705 \times 1.25 = 0.2131$ (0.21)	0.0081	0.0101	±0.00125	4.583
4th	30	0.2875	0.2449	0.2664 (0.27)	$0.2131 \times 1.25 = 0.2664$ (0.27)	0.0030	0.0123	±0.00151	4.545
5th	28	0.3750	0.2875	0.3323 (0.33)	$0.2664 \times 1.25 = 0.3330$ (0.33)	0.0007	0.0238	±0.00303	7.152

In the case of length and breadth measurements, considerable increase occurs in the difference between the maxima and minima for each instar particularly in the case of the latter instars. Length and breadth averages therefore can only be considered significant provided that the majority of measurements are made on larvae occurring in the overlap range of the two series, and that approximately equal numbers of larvae from the terminal regions of the series occur. They are, however, significant for practical purposes on account of the large overlap in range of the male and female series.

The size of individual larvae is also controlled by the relative amount of food available, which depends on a number of factors, including the instar of the host larva and the number of parasite larvae feeding on it

4. The Application of Dyar's Principle to *B. tachardiae* Larvae.

The factor of increase in head-width, obtained by dividing the average observed head-width in each instar by that of the previous instar and taking the average of these, is 1.250.

Table I summarises the observed head-width maximum, minimum, and average in each instar, and the calculated widths using Dyar's principle together with a statistical analysis of the results obtained. For this purpose, four figure measurements were employed in order to ensure that the results obtained should be as accurate as possible; in actual fact, however, measurements were not accurate to the third and fourth places. The figures in parenthesis are those which may be considered of value for practical purposes, such as instar determination, and it will be seen that between these there is a close approximation. The standard deviation was calculated

from the formula $S.D. = \sqrt{\frac{e_1^2 + e_2^2 + e_3^2 + \dots + e_n^2}{n}}$ where e equals the variation of each reading from the average and n the number of readings.

The probable error was calculated from the Gaussian formula,

$$PE = \pm 0.645 \times \frac{SD}{\sqrt{n}}$$

and the coefficient of variation from the formula, $CV = \frac{SD \times 100}{\text{mean}}$, the mean being the average of the readings.

It will be seen that in each case, except for the calculated width of the second instar, the average observed width and the calculated width correspond very closely. The probable error in every case is small. The measurements were all taken from living larvae.

The five larval instars of *B. tachardiae* may be grouped by the widths of the head-capsule, particularly if only the averages are considered; an instar can be characterised by the average width of the head-capsule. The range of head size in an instar is rather large and the extremes in some cases overlap. In actual practice, however, head-width is a safe indication of the instar of a larva, as the extremes seldom occur, being found only in the case of exceptionally large or small specimens, and the observed head-widths very closely approach the average.

In the case of 1st instar larvae 0.16 is recorded once only and 0.15 four times only. The maximum and minimum measurements of 2nd instar larvae are each recorded 3 times, and in five out of the six cases there is a possibility that the measurement was made on fixed larvae. The maximum and minimum figure for 3rd instar larvae each occur once only; a single cage slip record of 0.26 is disregarded as being inaccurate. In the case of 4th instar larvae the maximum and minimum occur once

only; two early records of 0.408 and 0.306 occur, but these are disregarded as inaccurate, as also is a single record of 0.53 for a 5th instar larva. The minimum for 5th instar larvae was only once observed.

It may be said that Dyar's principle, with the above qualifications, holds for larvae of *B. tachardiae*. Taylor (1931) has shown that this principle, with very similar qualifications, is applicable to the larval stages of the sawfly, *Phyllotoma nemorata*.

5. The Application of Dyar's Principle to Mandibular Length.

During the examination of the larval instars, the exuviae were found to be an extremely valuable aid to the interpretation of certain features. It was found, while taking measurements of the length of the mandibles both in mounted larvae and mounted exuviae, that the lengths of the mandible in a larva and in its exuviae are practically identical, being, however, very slightly larger in the exuviae. Table II summarises the lengths of mandible, maximum, minimum and average in the larva of each instar and in its exuviae.

TABLE II.

Mandibular Length of Larvae and Exuviae of B. tachardiae in each instar.

Instar	Mandibular length								Difference
	Mounted larvae				Mounted exuviae				
	Max.	Min.	Av.	No.	Max.	Min.	Av.	No.	
1st	0.03	0.022	0.0265	25	0.03	0.025	0.0266	14	0.0001
2nd	0.035	0.0325	0.0340	18	0.035	0.0325	0.0342	13	0.0002
3rd	0.0425	0.0375	0.0400	14	0.0425	0.0375	0.0410	12	0.00104
4th	0.0525	0.045	0.0488	17	0.0525	0.0475	0.0492	9	0.0004
5th	0.0675	0.055	0.0599	19	0.0675	0.055	0.0609	21	0.001

The factor of increase of mandibular length calculated in exactly the same manner as the factor of increase of head-width is 1.229. Table III summarises mandibular length together with the calculated lengths on Dyar's principle for each instar. It will be observed that the very close approximation between actual and calculated width practically excludes the chance of an ecdysis being missed, and makes it possible to identify the instar of fixed or mounted larvae or exuviae, for which purpose head-breadth is useless, particularly in the case of exuviae. The probable error is small in each case.

Willard (1927), describing the stages of *Microbracon mellitor*, Say, a parasite of *Platyedra* (*Pectinophora*) *gossypiella*, Saund., records the length of the mandible in the four larval instars, which are as follows:—0.03 mm., 0.045 mm., 0.055 mm., 0.07 mm. It will be seen that the last three instars form a regular series of the type described for *B. tachardiae*, and that between the first and second instars there is a disproportionate increase in mandibular length. The average factor of increase between his 2nd and 3rd and 3rd and 4th instars is 1.248. By multiplying the calculated mandibular length of each instar by 1.248, starting with the first, and by dividing the calculated length for each instar by 1.248 starting with the fifth, and taking the average of these figures, the following series of mandibular lengths is obtained:—0.0294, 0.0367, 0.0458, 0.0572, 0.0713. It is suggested that either the second instar in this species represents a combination of two instars, or that *M. mellitor*, like *B. tachardiae*, passes

THREE YEARS MOSQUITO CONTROL WORK IN CALCUTTA.

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1. Notes on the Mosquitos of Calcutta.

It was in December 1929 that the writer first tried to reduce the terrible mosquito nuisance which each winter plagues the City of Calcutta. His efforts were naturally confined to an attempt to alleviate conditions in the Bengal-Nagpur Railway's Headquarters Colony at Garden Reach, but it soon became obvious that by control in the relatively small area of land belonging to the railway very little could be accomplished, and that to achieve anything appreciable a very much larger acreage would have to be put under control. So when in the ensuing winter of 1930-31 other property owners in the vicinity became aware that this railway was attempting to do something and evinced interest in the matter, advantage was taken of this to form the Garden Reach Anti-Malaria Association, the initiation of which also received a considerable impetus from the virulent outbreak of malaria in the previous autumn at Budge Budge, some 18 miles down-river from the City. This outbreak, and the organisation of and area covered by the Association, are described by Covell (1932).

In order to check the efficiency of the anti-larval measures in force, eleven* "catching-stations" at pre-selected points throughout the area under control were instituted. In these catching-stations all mosquitos were caught indiscriminately, for a period of twenty minutes, early in the morning of the same day of each week. Two men, the Laboratory Assistant and the Laboratory Attendant, have between them carried out the whole of this work, and though perhaps the skill of the former results in a higher catch, other conditions being equal, than when the latter does the work in the absence of the Laboratory Assistant on tour with myself, yet the human factor has so far as possible been constant. On the other hand, the relative attractiveness to mosquitos of individual stations appears to be far from constant. Points considered in choosing a station were : presence of human blood at night, and absence so far as possible of smoke from cooking fires early in the morning, though as Gibbins (1933) has shown, cooking smoke from wood fires does not appear to influence the infestation of huts by the two principal African carrier Anophelines. The majority of stations are quarters of servants of Europeans. All are at ground-level, which, as will be seen subsequently, has a very important influence on the prevalence or otherwise of mosquitos. Nonetheless, as the recent work of Pittaluga and his collaborators (1932) so clearly brings out, for Anophelines (and presumably for all mosquitos) there is a set of factors influencing the choice of a building as a resting place that is exceedingly difficult to evaluate, and which in particular affects the sex ratio of the resting population. These factors have not been studied in India nor, so far as I am aware, for any mosquito except *Anopheles maculipennis*, on which the Spanish authors conducted their researches. As they are quite unknown in respect of our eleven catching-stations, they have perforce been neglected.

Before discussing the results of these catches, recorded in Tables I-III, which have yielded a total of over 19,000 specimens, it may be worth while examining the

*Recently increased to twelve with the inclusion of the Hooghly Jute Mill in membership of the Association. Figures throughout this paper, however, refer to the original eleven stations only, unless expressly stated otherwise.

TABLE I.—continued.

<i>M. annuliferus</i> ...	...	—	—	—	—	—	—	—	—	0	—	0	—	0	3	—
<i>M. uniformis</i> ...	...	—	—	—	—	0	0	—	1	0	—	0	—	1	12	0.1
<i>Fic. hybrida</i> ...	...	—	—	—	—	1	5	—	2	2	—	—	1	11	—	—
<i>Fic. "</i> ...	...	—	—	—	—	—	0	—	—	1	0	—	—	1	5	—
<i>Fic. luzonensis</i> ...	...	—	—	—	—	—	—	0	—	2	1	—	—	4	—	—
<i>Ar. obturbans</i> ...	...	0	—	2	—	0	—	1	1	—	—	—	—	1	—	—
<i>H. genurostirns</i> ...	...	2	—	0	—	1	—	1	1	—	—	—	—	4	9	0.1
<i>"</i> ...	...	—	—	0	—	—	—	—	—	—	—	—	—	5	—	—
<i>"</i> ...	...	—	—	1	—	—	—	—	—	—	—	—	—	0	1	—
<i>"</i> ...	...	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Total catch ...	...	1260	744	344	421	829	532	235	457	569	589	955	1094		8029	99.3
Density per catching minute		1.40	0.85	0.35	0.48	0.94	0.48	0.27	0.46	0.57	0.67	0.95	1.00	0.70		

growth of our knowledge of the Culicid fauna of Calcutta. The first list appears to be that of Giles (1902), who records eight species or varieties as known from the City, but these, through subsequent synonymy, became reduced to six. Paiva (1912) published the results of systematic breeding out of larvae taken in the course of the first anti-mosquito work of the Calcutta Corporation in 1909-10, and subsequently carried on as an investigation for the remainder of the year by the Zoological Survey of India. He recorded nine species, plus a "*Culex B.*" which is a mélange of the plain-winged brown-coloured species of the genus that have a banded proboscis. These, in the circumstances of his work, will have almost if not entirely consisted of *C. vishnui* and *C. tritaeniorhynchus*. As pointed out by Covell (1932), the *A. ludlowi* of these results is almost certainly *A. stephensi*. Two Anophelines (*sinensis* and *fuliginosus*) recorded by Giles are not in Paiva's list.

Paiva's paper, however, was put together during the former's illness by Gravely, and doubtless had he been able to complete it himself he would have compared his findings with the results of miscellaneous collecting in Calcutta, that appeared in the "Annotated Catalogue" and its "Supplement" of Brunetti (1907) and (1912). These three papers brought the list of known species up to twenty-one.

Iyengar (1920) gave a list of species found in the course of a survey of the area now occupied by King George's Dock, which is all within the present Association's control area. He added one species to Brunetti's list, and recorded the presence of another (*Mimomyia chamberlaini*) that has not appeared in our three years weekly catching in the same area.

With the inauguration of the Malaria Survey of India, knowledge again began to increase. In two papers Covell (1927 and 1931) added four species of *Anopheles* to the local list, while the long series of papers by Barraud (1923-1929) add three hitherto unrecorded Culicines, so that at the start of this work the total number of species recorded from Calcutta stood at 29.

There are 42 species in the present tables (which do not include one species bred only, not caught as adult, and one not caught in a regular catching-station). The tables do not include two of the species recorded by Brunetti and Barraud. The total list of CULICIDAE known from Calcutta therefore now stands at 47, of which 18 have been added by the present investigation. As this is merely the result of constant collecting in a well inhabited and industrialised area, there is no reason to suppose that the list is as yet complete, or that collecting (by breeding out in particular) would not add several further rarities to the list, which now stands as under Table IV, p. 557), species that have not been caught during the present investigation being distinguished by an asterisk.

TABLE II.

			1932-33														Totals ♂ ♀	Total for species	% of total catch
Rainfall ...	Catches made...	...	March	April	May	June	July	August	September	October	November	December	January	February					
0.7	1.1	11.7	7.4	9.9	9.0	9.5	3.8	9.0	0.0	0.8	2.6	65.5							
4	4½	4½	4	4½	4½	4	4½	4	5	4	4½	4½	4	4	52				
<i>A. subpictus</i>	3	3	9	12	5	1	4	4	2	1	0	—	44	131	2.5		
<i>A. vagus</i>	1	4	10	13	24	13	1	10	8	2	1	—	87				
<i>A. sundaicus</i>	—	5	4	7	6	8	14	1	2	4	2	—	53	187	3.5		
<i>A. culicifacies</i>	—	2	3	11	32	23	24	20	13	4	2	—	134				
<i>A. minimus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	6	0.1		
<i>A. varuna</i>	—	—	—	—	—	—	—	—	—	—	—	—	5	2	—		
<i>A. aconitus</i>	—	0	—	—	0	—	—	—	—	—	—	—	0	1	—		
<i>A. tessellatus</i>	—	1	—	—	1	—	—	—	—	—	—	—	2	3	6	0.1	
<i>A. stephensi</i>	—	—	—	—	—	—	—	—	—	—	—	—	3	3	12	0.2	
<i>A. annularis</i>	—	—	—	—	—	—	—	—	—	—	—	—	3	9	1	—	
<i>A. pallidus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—		
<i>A. ramsayi</i>	—	—	—	—	—	—	—	—	—	—	—	—	2	2	19	0.4	
<i>A. hyrcanus v. nigerrimus</i>	—	—	—	—	—	—	—	—	—	—	—	—	2	17	0	—	
<i>A. barbirostris</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	2	9	0.1	
<i>C. fatigans</i>	—	—	—	—	—	—	—	—	—	—	—	—	0	1	—		
<i>C. vishnui</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	7	3181	59.8	
<i>C. tritaeniorhynchus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	123	12.4	
<i>C. gelidus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	536	263	4.9
<i>C. bitaeniorhynchus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	58	11.2	
<i>C. sinensis</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	452	20	0.3
<i>C. sitiens</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	16	1	—
<i>C. mimeticus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	
<i>C. malayi</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	
<i>C. rubithoracis</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	
<i>L. fuscana</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	5	15	0.2
<i>S. fasciata</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	10	99	1.9
<i>S. albopicta</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	23	12	0.2
<i>Ae. iyengari</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	6	0	—
"	—	—	—	—	—	—	—	—	—	—	—	—	1	1	1	—	

TABLE II.—continued.

? <i>Skusea</i> sp. ...	—	—	—	—	—	—	0	—	—	—	—	—	0	1	—
" ...	—	—	—	—	—	—	1	—	—	—	—	—	1	—	—
<i>M. annulipes</i> ...	—	—	—	—	—	—	—	0	—	—	—	—	0	1	—
" ...	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—
<i>M. annuliferus</i> ...	—	—	—	—	1	0	0	0	—	—	—	1	2	11	0.1
" ...	—	—	—	—	0	4	1	3	—	—	—	1	9	—	—
<i>M. uniformis</i> ...	—	—	—	—	—	0	0	—	0	—	—	—	0	14	0.2
" ...	—	—	—	—	—	5	3	—	6	—	—	—	14	—	—
<i>T. crassipes</i> ...	—	—	—	—	—	—	—	—	0	—	—	—	0	1	—
" ...	—	—	—	—	—	—	—	—	1	—	—	—	1	—	—
<i>F. hybrida</i> ...	—	—	—	—	0	0	0	—	7	1	—	—	8	29	0.6
" ...	—	—	—	—	1	1	1	—	14	4	—	—	21	—	—
<i>F. luzonensis</i> ...	—	1	—	—	—	—	—	—	—	—	—	—	1	2	—
" ...	—	1	—	—	—	—	—	—	—	—	—	—	1	—	—
<i>Ar. obturbans</i> ...	0	0	2	—	0	0	2	2	2	—	0	0	8	24	0.5
" ...	1	1	0	—	2	2	0	0	8	—	1	1	16	—	—
Total catch ...	933	437	274	305	329	332	251	538	413	486	436	582		5316	99.2
Density per catching minute	1.06	0.45	0.28	0.35	0.34	0.34	0.29	0.48	0.47	0.50	0.44	0.66	0.47		

Within the 613 acres controlled by the Garden Reach Association there are now 451 breeding-places known and recorded on the control chart. Many of those listed under a single number are, however, multiple, such as sets of rainwater sumps under the roof pipes from a single goods transit shed, or the gully traps along one side of an individual road. The actual number of potential breeding-places that thus require regular scrutiny and treatment by the Association's staff is at least a thousand. For the last two years of the records, however, it may be taken that it is very exceptional for a breeding-place not to be discovered before it reaches the emergence stage. Hence the captures made in the catching stations mainly represent invasion of the controlled zone from its periphery, and thus the numbers of each species captured reflect more the powers of flight of a species than what would be its actual numerical prevalence in an uncontrolled area.

With this in mind a few notes on prevalence, numerical and seasonal, and other matters of interest relating to each species in the foregoing list, are given below.

Anopheles subpictus and *A. vagus*.—Whilst the second of these species is numerically the more common over the whole year, the former increases first, and in April–May is the commonest Anopheline in the catches. Thereafter *A. vagus* increases with the start of the rains, and remains numerous until November or December. Males of these two species being indistinguishable, the male catches have been allocated to one or the other by reference to the female catches of the same date.

Anopheles sundaicus.—This is the species previously known as *ludlowi*, and still so referred to in current Bengal Government official documents. It is the notorious malaria-carrier of the Netherlands Indies and the Andamans. The history of its recent invasion of the Calcutta District has been given up to the end of 1931 by Covell (1932), and the tale is as yet far from complete. The first specimens, however, to be captured actually within the City were those taken in our catching stations in November 1931. Thereafter it disappeared from our area until September 1932. As a result of investigations by the Public Health Department it was by then becoming increasingly evident to what an extent this species was depending for its spread on country boat transport. All the 1932 specimens (which included one freshly emerged male) having been taken in Kidderpore Dock catching-station, which is near the locks giving entrance to the docks from the Hooghly, the lock register was searched, and it was found that there exists a fairly frequent, though irregular, traffic of country boats from down river to load direct into ocean-going

TABLE III.

		1933-34														Totals ♂	Total for species	% of total catch
Rainfall ...	Catches made...	March	April	May	June	July	August	September	October	November	December	January	February					
0.0	4	3.0	4.4	7.7	15.8	17.2	14.6	10.5	9.6	0.0	0.0	0.0	0.1	78.5				
4	4.4	4.4	4.4	4.4	4.4	5	4	4.4	4.4	4	4.4	4.4	4	52				
<i>A. subpictus</i>	2	3	6	6	1	0	0	4	0	1	—	0	23	82	1.3		
<i>A. vagus</i>	2	4	9	12	4	2	3	15	7	0	—	1	59	250	4.1		
<i>A. "</i>	1	—	4	6	25	2	11	20	10	5	4	—	88	162	2	6	
<i>A. sundaicus</i>	0	—	10	43	40	9	27	20	10	3	0	—	162	2	4	0.1	
<i>A. "</i>	—	—	1	—	—	—	—	1	—	—	—	—	2	4	1	—	
<i>A. culicifacies</i>	—	—	2	—	—	—	—	2	—	—	—	—	4	1	—	—	
<i>A. "</i>	—	—	1	—	—	—	—	—	—	—	—	—	1	0	—	—	
<i>A. minimus</i>	0	—	—	—	—	—	—	—	—	—	—	—	0	1	—	—	
<i>A. "</i>	1	—	—	—	—	—	—	—	—	—	—	—	1	5	10	0.2	
<i>A. varuna</i>	1	2	—	—	—	—	—	—	0	1	—	1	5	3	11	0.3	
<i>A. "</i>	0	3	—	—	—	—	—	—	1	1	—	0	5	8	—	—	
<i>A. aconitus</i>	0	—	0	—	—	—	—	—	2	1	0	—	3	11	0.3		
<i>A. "</i>	1	—	1	—	—	—	—	—	4	0	2	—	8	0	—	—	
<i>A. tessellatus</i>	—	—	—	—	—	—	—	0	—	—	—	—	0	1	—	—	
<i>A. "</i>	—	—	—	—	—	—	—	1	—	—	—	—	1	1	—	—	
<i>A. stephensi</i>	—	—	—	—	—	—	—	0	1	—	—	—	1	2	—	—	
<i>A. "</i>	—	—	—	—	—	—	—	1	0	—	—	—	1	1	—	—	
<i>A. annularis</i>	—	1	—	—	—	—	0	0	0	0	—	0	1	11	0.3		
<i>A. "</i>	—	1	—	—	—	—	1	2	3	2	—	1	10	2	3	—	
<i>A. hyrcanus v. nigerrimus</i>	—	—	—	—	—	1	0	0	—	0	—	—	1	3	—	—	
<i>C. "</i>	—	—	—	—	—	0	—	1	—	1	—	—	2	—	—	—	
<i>C. fatigans</i>	167	226	83	18	6	11	25	31	37	71	72	66	813	3992	65.1		
<i>C. "</i>	763	460	270	120	54	47	96	120	155	320	378	396	3179	2	93	575	
<i>C. vishnui</i>	2	2	2	8	56	11	4	1	5	0	0	2	93	482	387	6.3	
<i>C. tritaeniorhynchus</i>	6	13	20	48	196	64	24	24	48	30	6	3	125	262	134	654	
<i>C. "</i>	—	1	—	1	0	49	59	3	11	1	—	—	0	2	0	2	
<i>C. gelidus</i>	—	5	—	6	3	115	50	33	28	22	—	—	262	134	654	10.7	
<i>C. "</i>	—	1	—	7	20	21	12	36	27	10	0	—	134	520	0	2	
<i>C. whitmorei</i>	—	1	—	16	37	39	74	153	152	46	2	—	520	0	2	—	
<i>C. "</i>	—	—	—	—	—	—	0	—	0	—	—	—	0	2	—	—	
<i>C. bitaeniorhynchus</i>	—	—	—	—	—	—	1	1	1	1	—	—	2	9	33	0.5	
<i>C. "</i>	1	1	—	0	0	3	1	2	—	—	1	0	24	0	1	—	
<i>C. sitiens</i>	2	1	—	1	2	4	3	10	—	—	0	1	0	1	—	—	
<i>C. "</i>	—	—	—	0	—	—	—	—	—	—	—	—	1	0	1	—	
<i>C. mimeticus</i>	—	—	—	1	—	—	—	—	0	—	—	—	1	0	1	—	
<i>C. "</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	
<i>C. fuscocephalus</i>	—	—	—	—	—	—	—	—	1	—	—	—	0	2	—	—	
<i>C. "</i>	—	—	—	—	—	—	—	—	—	0	2	—	2	0	1	—	
<i>C. malayi</i>	—	—	—	—	—	—	—	—	0	—	—	—	0	1	—	—	
<i>L. "</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	0	5	0.1	
<i>L. fuscana</i>	—	—	—	—	0	—	—	—	0	0	—	—	0	5	4	0.4	
<i>S. fasciata</i>	—	—	—	—	1	—	—	—	3	1	—	—	5	24	—	—	
<i>S. "</i>	0	0	—	0	0	0	2	2	0	—	—	—	4	20	0	1	
<i>Ae. andamanensis</i>	1	1	—	2	3	4	7	1	1	—	—	—	20	0	1	—	
<i>Ae. "</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	2	—	
<i>Ae. venustipes</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	
<i>M. annuliferus</i>	—	—	—	—	—	—	—	—	—	—	—	—	1	1	—	—	
<i>M. "</i>	—	1	0	1	0	—	0	1	0	—	—	—	3	25	0.4		
<i>M. uniformis</i>	—	2	1	1	2	—	5	6	5	—	—	—	22	0	12	0.2	
<i>F. "</i>	—	—	0	—	—	0	0	0	0	—	—	—	0	12	5	30	
<i>F. hybrida</i>	—	0	—	—	1	3	1	2	2	0	—	—	5	25	—	—	
<i>F. "</i>	—	1	—	—	—	3	2	1	7	11	—	—	25	—	—	—	

TABLE III.—continued.

<i>F. luzonensis</i> ...	...	...	—	—	—	—	—	1	—	—	—	—	—	—	1	1	—
"	"	"	—	—	—	—	—	0	—	—	—	—	—	—	0	—	—
<i>Ar. obturbans</i> ...	...	...	—	—	—	—	0	0	1	—	—	0	—	—	1	5	0.1
"	"	"	—	—	—	—	1	1	0	—	—	2	—	—	4	—	—
<i>H. genurostris</i>...	...	...	—	—	0	—	—	—	—	0	—	—	—	—	0	2	—
"	"	"	—	—	1	—	—	—	—	1	—	—	—	—	2	—	—
Total catch ...	...	...	950	730	412	297	452	384	414	491	535	532	465	471		6133	
Density per catching minute			1.08	0.73	0.42	0.34	0.41	0.44	0.42	0.50	0.61	0.54	0.47	0.54	0.54		

vessels in the docks. Only one point of origin of these craft, Shipganj, at the time of these captures, was suspected as indicating a possible unknown breeding focus of *ludlowi*, but on examination by the Public Health Department staff this was found to be free from the species; enquiry, however, showed that these craft had most probably all put in *en route* at Falta, a well known *ludlowi* focus. It is perhaps well for the City in general, and the dock area in particular, that no breeding-ground in the vicinity of the docks goes uninspected or untreated by the Association, irrespective of the species found.

TABLE IV.

<i>Anopheles subpictus</i> , Grassi.	<i>Culex fuscocephalus</i> , Theobald.
<i>Anopheles vagus</i> , Dönitz.	<i>Culex malayi</i> (Leicester).
<i>Anopheles sundanicus</i> , Rodenwald.	<i>Culex rubithoracis</i> (Leicester).
<i>Anopheles culicifacies</i> , Giles.	<i>Culex seniori</i> , Barraud.
<i>Anopheles minimus</i> , Theobald.	<i>Lutzia fuscana</i> (Wiedemann).
<i>Anopheles varuna</i> , Iyengar.	<i>Stegomyia fasciata</i> (Linnaeus).
<i>Anopheles aconitus</i> , Dönitz.	<i>Stegomyia albopicta</i> (Skuse).
<i>Anopheles tessellatus</i> , Theobald.	<i>Aedes iyengari</i> , Edwards.
<i>Anopheles stephensi</i> , Liston.	<i>Aedes andamanensis</i> , Edwards.
<i>Anopheles annularis</i> , v.d. Wulp.	<i>Skusea</i> sp.
<i>Anopheles pallidus</i> , Theobald.	<i>Aedomyia venustipes</i> (Skuse).
<i>Anopheles ramsayi</i> , Covell.	<i>Mansonioides annuliferus</i> (Theobald).
<i>Anopheles hyrcanus</i> var. <i>nigerrimus</i> , Giles.	<i>Mansonioides annulipes</i> (Walker).
<i>Anopheles barbivrosus</i> , v.d. Wulp.	<i>Mansonioides uniformis</i> (Theobald).
<i>Culex fatigans</i> , Wiedemann.	<i>Taeni rhynchus crassipes</i> (Wulp).
<i>Culex vishnui</i> , Theobald.	<i>Ficalbia hybrida</i> (Leicester).
<i>Culex tritaeniorhynchus</i> , Giles.	<i>Ficalbia luzonensis</i> (Ludlow).
<i>Culex gelidus</i> , Theobald.	<i>Mimomyia chamberlaini</i> , Ludlow.*
<i>Culex whitmorei</i> (Giles).	<i>Armigeres obturbans</i> (Walker).
<i>Culex bitaeniorhynchus</i> , Giles.	<i>Armigeres magnus</i> (Theobald).*
<i>Culex sinensis</i> , Theobald.	<i>Megarhinus splendens</i> (Wiedemann).
<i>Culex sitiens</i> , Wiedemann.	<i>Harpagomyia genurostris</i> (Leicester).
<i>Culex mimeticus</i> , Noé.	<i>Chaoborus manilensis</i> (Schiner).

Anopheles culicifacies.—A great rarity. An odd specimen or two seems to turn up regularly in the early hot weather, and again when the rains are well established. It obviously plays no part in local malaria causation.

Anopheles minimus.—Covell (1932) considered my records of this species doubtful, being all founded on males. I have, however, kept the species in the local list, as in 1932 a female was taken which agreed with this form more closely than with the other forms of the *fluviatilis*-group. Considering that river steamers from East Bengal and Assam regularly berth in the Association's area, especially at the Tea Warehouse near Kidderpore Docks, the capture of an occasional transported specimen is quite possible. It must be admitted, however, that none of the specimens had been taken at that catching-station.

*Species not caught during present investigation.

Anopheles varuna.—Turns up regularly in small numbers in the autumn and cold weather, and, like *culicifacies*, also in April. It is far too rare to play any part in malaria causation.

Under this species I have included the three single records in 1931 of *A. listoni* (*fluviatilis*), considered to be doubtful by Covell (1932). No females have been taken, and Calcutta appears to be considerably removed from any area where this form has been identified with certainty in recent years since the *fluviatilis*-group was better understood.

Anopheles aconitus.—Occurs in small numbers in every month except September and October. It was the only possible carrier-species I caught when investigating a small outbreak of malaria at a works on the west bank of the Hooghly opposite Garden Reach, when both the Manager and his wife contracted malaria.

Anopheles tessellatus.—A great rarity here, and not hitherto recorded from Calcutta. A single specimen has turned up each year.

Anopheles stephensi.—If one judged from these records, the species would rank among the rarest Anophelines of Calcutta. This is certainly not so. Though no special search has been made for it other than one to satisfy me that in Garden Reach, as throughout the City, a very large proportion of the overhead cisterns are breeding it,* yet the larvae brought in from time to time and bred out in the laboratory have far exceeded in numbers the adults captured in nature. However, no anti-larval work in the roof-tanks has been undertaken, as there has been no staff available for such time-consuming operations, and my policy has been to persuade the various members of the Association to render the cisterns in their ownership permanently mosquito-proof on the lines recommended by Covell (1932). A census of the overhead tanks and cisterns within the control area revealed that there are 616, of which only 7.4 per cent. were originally mosquito-proof. Subsequent to this the tanks in the railway area, numbering 69, and those of Messrs. MacNeill & Co., have all been made permanently mosquito-proof, but the other members have not yet followed suit. The present is, of course, a very unsuitable time to urge measures involving considerable financial expenditure.

The real reason, then, underlying the apparent rarity of *stephensi* in the check catches is not its absolute paucity of numbers, but the fact that its daytime resting-places are mainly not in houses, and in fact are unknown. None of the literature that I have been able to consult makes any mention of the adult day-time resting-places, but several fellow-workers in Calcutta have discussed with me the extreme difficulty of finding resting adults. The species remains, therefore, a major problem to the executive of the Association, and the curious anomaly exists that, within its controlled area, the most dangerous mosquito at present existing is the only one against which virtually no measures have been taken.

Anopheles annularis.—Occurs throughout the latter half of the rains and the cold weather, reaching its maximum in October–December, being the third most prevalent Anopheline in the catches. Were these made in cattle-sheds instead of in human habitations, its prevalence would probably be raised, for it has a vastly greater affinity for cattle than for man, as the following figures, relating to Chengail, some seventeen miles from Calcutta, show. The catches at Chengail were made in connection with checking the efficacy of the anti-*ludlowi* work at that station carried out by the Public Health Department, to which the railway contribute their share of the cost. The figures apply to 20-minute catches in railway menials' quarters and in a small cattle-shed adjacent thereto (Table V, p. 559).

The preference for cattle over man, or for cattle-sheds as a resting-place as compared with human dwellings, is thus of the order of 50 : 1.

*Iyengar (1920) recorded 37.7 per cent. of 453 cisterns throughout the City as positive for this species; Basu (1930) 28.9 per cent. of 560 cisterns in the central portion of the City.

Anopheles pallidus.—A very great rarity. Similarly, in the Chengail catches referred to under the preceding species, only 2 in the dwellings and 54 in the cattle-shed were taken in the period covered by the table.

Anopheles ramsayi.—Also very rare. According to Covell (1932) this is the species referred to by Brunetti (1907) and Iyengar (1920) as *jamesi*, from which it was not differentiated until 1926. Covell (1931) throws doubt on all records of true *jamesi* from Bengal.

Anopheles hyrcanus v. *nigerrimus*.—Only appears in the rains and cold weather. I think this species is capable of extended flights at the onset of the cold weather, when the rice-fields in which it has been breeding are drying up, and when it is perhaps seeking permanent marshes and tanks in which to spend the winter and dry season. On these flights it is apparently attracted to light, and I have on several occasions noticed anything up to a dozen specimens resting on a wall round a lamp in the evening. As it adopts the characteristic Anopheline attitude very distinctly, I have on more than one occasion been spoken to, by more observant laymen, on the subject of the number of Anophelines about. The flights seem to consist mainly of females.

TABLE V.

	1931		1932										Total
	Nov.	Dec.	Jan.	Feb.	Mar.*	Apr.	May	June	July	Aug.	Sept.	Oct.	
Menials ...	36	17	6	11	4	7	0	3	0	6	5	14	109
Cattle ...	484	710	454	518	306	253	8	21	45	240	308	1,650	4,997

*No catch for two weeks, all staff being on tour elsewhere on the line.

Anopheles barbirostris.—Very rare in the catches. Seldom bites man, though I was once attacked in a standing train by a specimen that returned in a further attempt after having been driven off. There must be a large production of this species in the tanks and swamps on the south-west of the control area.

Culex fatigans.—Easily the predominant mosquito of the area. As work on its bionomics comprises the second part of this paper it is not further dealt with here.

Culex vishnui.—It is possible that under this species *C. barraudi* and *C. whitei* are included, but the former is only recorded from the Punjab and Western Himalaya, and the latter from the Assam Hills. A few dissections done at the commencement of the work proved all to be *vishnui*, but there has not been time to examine the genitalia of all the numerous males taken in the collections. The females of the three species are in any case inseparable. The curve of prevalence of this species is the reverse of that of *fatigans*, indicating that it finds optimum conditions in pools that are frequently freshened by rain.* In 1931–32 there appeared to be breeding between June and December, i.e., from a month after the commencement to a month after the finish of the rains. But in 1932–33, whilst the same phenomenon appeared generally to hold, yet from October onwards there was a notable decrease in the number of males captured. Now in this species at least, the proximity of a breeding-place seems to be correlated with a high percentage of males in the catch. This is well brought out by the record for July 1931. In that month, which has shown almost the heaviest precipitation of any month in the present records, the Inspector, fearing to exceed his budget allotment for oil, lost control of the large grassy area east of King George's Dock along Nimak Mahal Road, and this species bred very heavily

*Gater (1933) in Malaya, however, shows the maximum annual incidence associated with the minimum monthly rainfall.

in the vegetation-covered swamp thus formed. The same phenomenon occurred to a far lesser extent in the year following, consequent on a reserve fund for oil clearing the Inspector of budgetary apprehensions, and the Port Commission gradually completing a programme of filling and levelling this area. Thus in the autumn of 1932, though there was a not inconsiderable number of this species about, yet I think they were all females entering the area to feed, and bred beyond it. Coutts Milne (1933) considers that this species may fly over a mile from its breeding-place

Culex tritaeniorhynchus.—Found in much smaller numbers than *vishnui*, but apparently following the same laws governing prevalence. It is virtually absent for six months commencing with December.

Culex gelidus.—Appears to follow the same laws as the two preceding species, but whereas the breeding-places of these are well-known, and larvae, if required, easy to obtain, the breeding-places of *gelidus* appear to be exceedingly obscure. Coutts Milne (1933) failed to find the breeding-place of this species when investigating mosquitos in Taiping (F.M.S.). Paiva (1912) found over half the very small total bred by him in earthen pots, the remainder in tanks and open drains. For the very small numbers bred from larval catches here probably much the same would apply, but the very small breeding found bears no relation to the large numbers in which the species is from time to time taken. No breeding could be found to account for the heavy catches of October–December 1931 and 1932.

Now in July 1932 there was a considerable prevalence of *gelidus* at Garden Reach, far more so than the catches indicate. They swarmed in bamboo clumps, and low down in rough grass. As it was certain that there was no local breeding to account for this, an attempt was made to prove invasion from beyond the control zone by means of fly-paper screens exposed on the flat roof of a tall building. Not a single mosquito of any species was captured, though we trapped numerous other insects, mainly Chironomids. Watching beside the screens for an hour after dark on two occasions there appeared to be a steady drift of insects from south to north (*i.e.*, with the wind) across the beam of an electric torch. Three observations gave as follows :—

Time watched.					Northward	Southward
?	...	...	...	...	83	17
38 minutes	...	...	...	...	90	10
35	„	...	...	...	54	13

but these insects may not have been mosquitos at all, though at dusk on the occasion of the first experiment a swarm of male mosquitos was dancing high over our heads over the building, and the bushes around it were, as mentioned, full of *vishnui* and *gelidus*.

When the invasion of October 1932 occurred (*vide* Table II), the catching staff drew my attention to the fact that *C. gelidus* sits very close and is very sluggish to disturb. They also reported coal-waggons coming into Garden Reach across the railway waggon ferry from Shalimar* as being full of this easily recognisable species. I inspected the contents of a few waggons myself at Shalimar one afternoon, and there appeared to be some truth in their contention. But if *gelidus* (or any other species) will remain at rest through the shunting and bumping involved in lowering a waggon on to a ferry steamer, why should the same reversed procedure force the insect to take flight on reaching the other side of the Hooghly?

From June 1933 to January 1934 female *C. gelidus* caught in the catching-stations were classified for stage or abdominal development, as explained in Part 2 of this paper. Of 472 specimens so examined, 38.5 per cent. were found in stage I (unfed ovaries immature) and 31.3 per cent. in stage VII (ovaries mature, gut empty). It

*For more detailed description of this procedure, as it affects mosquito importation, see Part 2 on the bionomics of *C. fatigans*.

would thus appear that the controlled area is invaded from beyond the periphery by unfed specimens, which do not remain in houses either to feed (the species seldom bites man), or after feeding, but are found in houses when digestion is complete and the ovaries ripe.

An interesting confirmation of this was obtained on 18.ix.1933. At 6.45 p.m. my Laboratory Assistant's quarters, situated on the ground-floor of a big double-storey block of buildings, were suddenly invaded by a swarm of mosquitos. Having his catching apparatus with him for work early next morning, he caught these invaders of his house as quickly as possible.* The catch consisted of:—

<i>Culex vishnui</i>	...	...	...	...	19 ♀
<i>Culex tritaeniorhynchus</i>	...	...	...	...	30 ♀
<i>Culex gelidus</i>	...	...	...	...	243 ♀ (=82 per cent. of catch)
<i>Stegomyia fasciata</i>	...	...	...	...	1 ♀
<i>Mansonioides uniformis</i>	...	...	...	...	1 ♀
<i>Anopheles nigerrimus</i>	...	...	...	...	1 ♀

The flight continued until 7.30 p.m. and ceased as suddenly as it had begun. The mosquitos, at least the *vishnui*-group, were hungry. By morning any of them that had escaped being caught had left the house. Of the *Culex gelidus* all but one, and all the *vishnui* and *tritaeniorhynchus* captured, were in stage I. It is certain that no breeding-place capable of producing such a big flight existed within the controlled area, and the flight must have originated beyond its limits. It is noteworthy that no males accompanied it, and that therefore presumably the females had been fertilised before fighting. The flight was at a very low elevation, as it was not noticed in the upper storey of the block.

To indicate the flight potentialities of *C. gelidus*, a staining experiment was carried out in November 1933. At Shalimar, on the right bank of the Hooghly, 403 eosin stained bred adults were released in the evening of 4.xi.1933. Two stained females were recovered on a ferry steamer at Garden Reach (left bank) on the evening of the 6th, and a stained male in No. 11 bungalow catching-station on the morning of the 8th. This does not actually prove direct flight, as ferry transportation (*vide* Part 2 of this paper) may very possibly have occurred, which bears out the contention of my staff recorded above.

The bionomics of *gelidus* are still exceedingly obscure.

Culex whitmorei.—Not found in the regular catching-stations until the third year of observation. For the original record of this species from Calcutta see under *Ficalbia hybrida* (p. 563).

Culex bitaeniorhynchus.—This species is attached in its larval stage to *Spirogyra*, as I have shown elsewhere (Senior White 1926). The few specimens taken are doubtless from unkilld patches of this alga in tanks. I have never known this species in sufficient numbers to be a nuisance, or to bite man.

Culex sinensis and *C. sitiens*.—Are both represented in the catches by single specimens only. The latter, at least, probably does not breed so far up the Hooghly as Calcutta, and is a country-boat importation. It is an intolerable biter in areas where it occurs commonly.

Culex mimeticus.—The capture of an unrubbed male of this species is one of the curiosities of the results obtained. The specimen is true *mimeticus*, and not the Oriental *mimulus*. The nearest known breeding-grounds of *mimeticus* to Calcutta are in the Darjiling Himalaya. The catching-station where the specimen was taken is close to the berth of the river steamers in King George's Dock, but the state and sex of the specimen would seem to postulate an unknown winter Plains focus of this

*The quarters had not been specially emptied of mosquitos in advance, but for some weeks previously Garden Reach had been very free of mosquitos of all kinds.

species, as well as its breeding on board. The solitary female taken in 1933 was in a catching-station remote from any possible river steamer importation.

Culex fuscocephalus.—This species, though previously recorded from Calcutta, did not appear in the catches in the Association's area until 33 months after these commenced. My experience of it is that it breeds in shallow grassy clean-water pools, so its appearance in winter was not to be expected.

Culex malayi.—Hitherto only known from a rock-pool in North Kanara. As an odd specimen turns up each year it must have other breeding-places locally of a very different nature.

Culex rubithoracis and *C. seniori*.—Belong to the subgenus *Lophoceratomyia*. The former is Malayan, the latter new, and I think the first mosquito to be originally described from Calcutta since *Anopheles subpictus*.

Lutzia fuscana.—As this species is dependent for its existence on dense breeding of other species, mainly *C. fatigans*, on which as a larva it is predacious, one would not naturally expect it to be common in a well controlled area. Odd specimens are taken more or less throughout the year, however. Iyengar (1920) states that it bites exceedingly viciously by day, and flies low. I have no personal experience of it as a biter and should have thought that its great size would have militated against successful attack on a waking person.

Stegomyia albopicta and *S. fasciata*.—Owing to their very short range of flight, adult catches of these two species do not accurately reflect breeding conditions within this or any other area. This is well brought out in the tables given by Kerr (1933). A real nuisance due to *fasciata* may exist that is not reflected in the least in the nearest catching-station. The Association has not the staff for regular house-to-house inspections of such complicated buildings as Europeans' bungalows, but all living within the area are encouraged to report mosquito nuisance by telephone. Each complaint is entered as received in a book, and the Inspector then visits and subsequently endorses the page as to the species found and action taken. If *Stegomyia* is the cause, the householder, or his servants, are given the necessary instructions. In consequence, comparatively few cases of *Stegomyia* breeding are now discovered. Out of sixteen entries in the book from August 1932 to March 1933 I find only five apply to *Stegomyia*. With fire-buckets all regularly treated with a Cresol disinfectant, and *malis* fined for making breeding-places under flower-pots, etc., it has long been quite rare to encounter any *Stegomyia* nuisance throughout the area. Density in 1933 was only 9 per cent. of what it was in 1931. Dengue, which in former years attacked a very large number of the railway officers and their families each summer, has now virtually ceased to exist. Similarly the officers of the British India S.N. fleet, who formerly suffered so severely that at times ships were actually delayed in putting to sea, have practically ceased to go sick with this disease.* For the B.I. fleet a special Sub-Assistant Inspector is employed under the Association for work on the steamers themselves, in docks and moorings. So valuable has his work been found that the majority of the other Shipping Lines entering the Port of Calcutta are considering adopting similar measures.

As regards the relative prevalence of the two species of the genus, it would seem that during the present century a change has taken place. Brunetti (1907) records *albopicta*, but not *fasciata*, from Calcutta. In writing his supplement of 1912, he notes under *fasciata*, "not so common as *scutellaris*." Of the total of the two species bred by Paiva (1912) 35.8 per cent. were *albopicta*, whereas only 5 per cent. of the catch of 1931-32 was this species, which now appears only during the rainy season. It should be noted that all tree-holes throughout the control area are kept filled with

*Dengue in a European means the best part of a month's absence from duty. As most Europeans are on salary scale and entitled to sick leave, it is obvious that control of dengue alone repays the cost of the Association many times.

sand and asphalt. Dissection of a few males of *albopicta* indicate that our local species is really this, and not one of the new species recently discovered by Barraud (1931), that are only separable by the genitalia.

Skusea sp.—A solitary female was submitted to Capt. Barraud who states that it is unlike anything in the Kasauli collection, but is in too bad order to describe.

Aedes iyengari.—An Eastern Sub-Himalayan species. There is no record as to the locality from which the type specimens were bred, but it apparently breeds on the Plains, as a single specimen usually turns up each year.

Aedes andamanensis.—A single female in the third year of control only. It is a widely distributed species of Malayan affinities, so its appearance in Calcutta is not extraordinary.

Aedomyia venustipes.—The catch averages one specimen a year. It has been recorded from the area before by Iyengar (1920), and I took an additional male on a ferry steamer in March 1933.

Mansonioides annulipes, *M. annuliferus** and *M. uniformis*.—Breeding of these species evidently starts with the rains. The second and third are the most commonly taken. The second species alone has yielded males, and the breeding-places are evidently remote.

Taeniorhynchus crassipes.—A solitary specimen in two years, but recorded from Calcutta before by Brunetti (1912).

Ficalbia hybrida.—Far from uncommon, though it does not breed within the control area. The heavy catch in November 1932 is interesting, as illustrating the extent to which mosquitos are transported into an area. Of the 21 specimens taken in the month, 19 were captured in a single round of the catching-stations on 13th–14th. All these were taken in the northern half of the area, where there is not a single tank with *Pistia*, among which the species breeds. I do not think it bites mammals at all, and so would be unlikely to enter the area of its own volition. That swarms of mosquitos (like other insects) are thus picked up, presumably by ascending air-currents, and deposited a long way off is extremely probable. The hypothesis is as old as Wallace (1876) and instances were discussed by several speakers at the discussion following on the paper of Christophers (1921). Ball (1918) presents conclusive evidence of the wind-borne migration of two American species of *Aedes* to a lighthouse built on a submerged shoal, from the Florida coast and the Cuban coast, the minimum distances concerned being 105 and 95 miles respectively. A most interesting instance occurred at Garden Reach on the night of 28th November, 1932. My clerks were working late that night, and suddenly found the office invaded by mosquitos. A collection of these that they made contained :—

Culex gelidus 4♂ 2♀; *C. whitmorei* 3♂; *C. tritaeniorhynchus* 4♂; *C. vishnui* 3♀;

Ficalbia hybrida 3♂; *Anopheles hyrcanus* 2♂.

Now in this collection was included *C. whitmorei*, never heretofore found in the catches, and hitherto unrecorded from Bengal,† and I think that this swarm, and the heavy influx of *F. hybrida* of a fortnight earlier, were the results of air-current transportation. A similar swarm was taken in No. 11 bungalow catching-station on 2.xii.33.

Ficalbia luzonensis.—Calcutta is the only place in India from which this species has been recorded. Unless James' specimens from Colombo (James, 1914) were bred,

*Since this paper went to press Barraud (Fauna India, Dipt. 5, 1934, p. 130) has shown that a second species, *M. indianus*, Edw., has been confused under this name; both are recorded from the area which is the subject of the present paper.

†I obtained 3 specimens of this species in the check catches from Khargpur (73 miles west of Calcutta) in the weeks ending 26th November and 3rd December, 1932. I have not seen the species there before or since.

nothing is known of the breeding habits of the species, and in any case there is nothing on record.

Armigeres obturbans.—Naturally rare in an area where all foul privy sumps and the like are regularly oiled. The increased numbers in November 1932 are due to one sump being missed from a round, and shows the extreme value of adult check catches in working a mosquito control.

Harpagomyia genurostris.—It must be pure chance that leads odd specimens of this myrmecophilous species into a catching-station. The species is not so rare, however, as this record would indicate, as it was bred in considerable numbers in August 1932 from water in the axils of *Colocasia* leaves in the garden of the Roman Catholic Mission School on Nimak Mahal Road.*

Megarhinus splendens.—This species does not appear in the adult catches at all. It is of course too large to be taken in the catching apparatus used, if it ever rests in houses, which I doubt. Paiva (1912) records its presence more or less throughout the year, and I have breeding records for July, August, October, November and February, but no special attention has yet been paid to this point.

Chaoborus manilensis.—Not taken in any regular catching-station. A female was captured on board a ferry steamer at Garden Reach on the night of 22.iii.34.

A study of Tables I to III brings out clearly that of the 46 species of mosquitos known from Calcutta very few are of economic importance or present in sufficient numbers to constitute a nuisance. Unfortunately, the vectors of all the mosquito-borne diseases, malaria, filariasis, dengue and yellow fever, are present in abundance, but omitting *A. stephensi*, the true intensity of which, for reasons explained on p. 558, adult check catches fail to reveal, the only species present in abundance are :—

	1931-32	1932-33	1933-34
<i>Anopheles subpictus</i> ...	4.8	5.8	5.4
<i>Anopheles vagus</i> ...			
<i>Culex fatigans</i> ...	72.2	59.8	65.1
<i>Culex vishnui</i> ...	11.8	17.3	15.7
<i>Culex tritaeniorhynchus</i> ...			
<i>Culex gelidus</i> ...	5.8	11.2	10.7
<i>Stegomyia fasciata</i> ...	3.1	2.1	0.4
<i>Stegomyia albopicta</i> ...			
Percentage total catch ...	97.7	96.2	97.3

Work against these eight species, therefore, is all that is required, plus a constant vigilance regarding *A. sundanicus*.

It is at once apparent that *Culex fatigans* is predominantly the major pest in Calcutta. Next come the pool-breeding *Culex*, which, with *gelidus*, James (1914) classes as "migratory species"; these, while retaining their habit of breeding in swamps and natural pools at a distance from centres of population, have the habit of

*The curious elliptical swinging motion adopted by this insect at rest appears to be peculiar to this species among mosquitos. It was first mentioned by James (1914), but Farquharson (1918), a very keen observer, made no mention of it in regard to the African species. I have noticed the same thing exactly with certain small Tipulids, *Trentepohlia trentepohlii* and (?) *Mongoma pennipes*, in Ceylon.

TABLE III.
Analysis of the Mandibular Length of the Larvae of B. tachardiae in each Instar.

Instar	No.	Mandibular length observed in both larvae and exuviae			Calculated length	Difference in average observed and average calculated length	Standard deviation	Probable error in average	Co-efficient of variation
		Max.	Min.	Average					
1st	39	0.0300	0.0220	0.0265	—	—	0.00219	± 0.000236	8.264
2nd	31	0.0350	0.0325	0.0341	$0.0265 \times 1.229 = 0.0326$	0.0015	0.001196 (or 0.0012)	± 0.000145	3.508
3rd	26	0.0425	0.0375	0.0405	$0.0326 \times 1.229 = 0.0400$	0.0005	0.00184	± 0.000243	4.535
4th	26	0.0525	0.0450	0.0489	$0.0400 \times 1.229 = 0.0492$	0.0003	0.0021	± 0.000278	4.295
5th	40	0.0675	0.0550	0.0604	$0.0492 \times 1.229 = 0.0604$	0.0000	0.00316	± 0.000337	5.228

TABLE IV.
Head-width and Mandibular Length Calculations for B. tachardiae Larvae in each Instar

Instar	Approximate average head-width observed	Head-width calculated using approximate mandibular length increase ratio 1.23		Average mandibular length observed	Mandibular length calculated using head-width ratio 1.25	
		Min.	Max.		Min.	Max.
1st	0.14	—	$0.1773 \div 1.23 = 0.1432$ or 0.14	0.0265	—	$0.03092 \div 1.25 = 0.02474$
2nd	0.18	$0.14 \times 1.23 = 0.1722$ or 0.17	$0.2181 \div 1.23 = 0.1773$ or 0.18	0.0341	$0.0265 \times 1.25 = 0.03312$	$0.03866 \div 1.25 = 0.03092$
3rd	0.22	$0.1722 \times 1.23 = 0.2117$ or 0.21	$0.2683 \div 1.23 = 0.2181$ or 0.22	0.0405	$0.0331 \times 1.25 = 0.0414$	$0.04832 \div 1.25 = 0.03866$
4th	0.27	$0.2117 \times 1.23 = 0.2605$ or 0.26	$0.33 \div 1.23 = 0.2683$ or 0.27	0.0489	$0.0414 \times 1.25 = 0.05175$	$0.0604 \div 1.25 = 0.04832$
5th	0.33	$0.2605 \times 1.23 = 0.3204$ or 0.32	—	0.0604	$0.05175 \times 1.25 = 0.06469$	—

through five larval stadia of which one has been overlooked. This is further substantiated by the recorded lengths of the larva of each instar, *viz.*, 1.2, 1.7, 1.9 at the beginning of the instar and 2.4 at the end, and 4 mm.; for it seems possible that these five successive lengths actually belong to five successive instars.

6. The Similarity of the Factors for Average of Head-width and Mandibular Length.

It will also be observed that the ratio of increase of head-width, and the ratio of increase of mandibular length are similar. Table IV makes it clear that for practical purposes the substitution of head-width increase ratio for mandibular length increase ratio and *vice versa* can be used to obtain approximate figures. Thus, provided that one ratio is known and either the average mandibular length or head-width for one instar is known, it is possible to state approximately the average mandibular length or head-width as the case may be of the remaining instars. Similarly, if the head-widths of the first two instars and of the last are known, the number of instars can be calculated, a similar calculation could be made if the mandibular lengths of the 1st and 2nd and ultimate stage larvae or exuviae are known.

In the case of ectoparasites it is frequently possible to obtain and mount all the moults, though measuring or mounting the larvae themselves may be impracticable; in these cases the increase factor can be obtained from the mandibles of the exuviae and applied to whatever larval head-measurements it has been feasible to obtain.

It will be seen of course that numerous other uses could be made of these ratios in calculating widths and lengths, and calculating the number of instars.

The factor obtained by taking the average of the mandibular increase factor and the head-width increase factor will give an even closer approximation to the observed widths.

The author suggests that this theory may be valid for other ectoparasitic Braconids. Preliminary investigations carried out with *Aphrastobracon flavipennis*, Ashm., also an ectoparasite, whose normal host is *Eublemma scitula*, but which can also be bred on *E. amabilis*, indicate that similar results will be obtained with this species.

7. Growth of the Larva during the five larval Stadia.

It must be clearly understood that, owing to the probable double series of larvae and the fact that measurements taken from living larvae can only be approximate, the figures quoted under this heading are used only as a rough indication of the lines along which growth is believed to proceed.

The maximum, minimum and average lengths and breadths of each instar together with the number of observations are recorded in the descriptions of the instars. It will be seen that the ratio of length to breadth remains fairly constant in each stadium, though it decreases in a regular series from instar to instar, the ratio figures being 4.0, 3.66, 3.4, 3.35 and 3.11.

Both the average length and the average breadth in each stadium increase in a regular series, the factors of increase being 1.47 and 1.56 respectively, calculated on Dyar's principle, and in each case growth is at a maximum from the 4th to the 5th instars, and approximately equal between the other larval stadia. Table V records the average observed and the calculated lengths and breadths in each instar.

From the data obtained it has not been possible to calculate the average volume of the larva of each instar; however, since the ratio of length to breadth does not vary

TABLE V.

Lengths and Breadths of B. tachardiae Larvae in each Instar.

Instar	Average observed length	Calculated length	Average observed breadth	Calculated breadth
1st	0.76	—	0.19	—
2nd	1.06	$0.76 \times 1.47 = 1.12$	0.29	$0.19 \times 1.56 = 0.296$
3rd	1.53	$1.12 \times 1.47 = 1.65$	0.45	$0.296 \times 1.56 = 0.46$
4th	2.11	$1.65 \times 1.47 = 2.43$	0.65	$0.46 \times 1.56 = 0.72$
5th	3.48	$2.43 \times 1.47 = 3.57$	1.12	$0.72 \times 1.56 = 1.12$

greatly in each stage, the volume of the hypothetical cylinder which would contain the larva of each stage can be used to calculate the ratio of the increase in volume using the formula :—

$$V = 1 \left[\frac{\alpha}{2} \right]^2 \pi$$

The volume calculated in this way increases in a regular series, the factor of increase being 3.6 ; the maximum increase occurs between the 4th and 5th instars and the minimum between the second and third.

Table VI records the calculated volume of the hypothetical cylinder for each instar, together with the volume obtained by multiplying the calculated volume for each instar by 3.6 starting with the first, and dividing the calculated volume for each instar by 3.6 starting from the fifth, and averaging these figures.

TABLE VI.

Calculated Volumes of B. tachardiae Larvae in each Instar.

Instar	Calculated volume of hypothetical cylinder	Calculated volume using the factor 3.6	Difference
1st	0.022	0.021	0.001
2nd	0.07	0.076	0.006
3rd	0.24	0.275	0.035
4th	0.70	0.99	0.29
5th	3.43	3.56	0.13

Larvae are generally supposed to double their weight, and thus also their volume, progressively instar to instar. *B. tachardiae* larvae, however, increase in volume by the approximate factor 3.6 ; linear measurements should therefore increase by $\sqrt[3]{3.6} = 1.51$, the actual figures obtained for length and breadth being 1.47 and 1.56 respectively.

In order to obtain a check on this volume increase of 3.6, ten 1st instar larvae and five 5th instar larvae were weighed on a microbalance, and the approximate factor for weight increase calculated from the formula

$$\text{Increase} = \sqrt[4]{\frac{W_2}{W_1}} = \sqrt[4]{\frac{0.0032}{0.000012}} = 4.04$$

where W_1 was the weight of a first instar larva and W_2 the weight of a fifth instar larva.

This calculation, though admittedly made on a very small number of larvae, may be taken as an indication that the volume increase factor 3.6 is approximately correct and that these larvae in fact increase by a figure lying between 3 and 4 times per instar.

The growth of the head-capsule appears to be independent of increase in body size, its width and the length of the mandible increasing from instar to instar by figures not far removed from $\sqrt[3]{2} = 1.26$, the respective figures being 1.25 and 1.229. The head thus increases by the normal "double" from instar to instar.

8. Summary.

The egg, the five larval instars, cocoon, prepupa and pupa of *Bracon tachardiae*, Cameron, are described.

Two series of larvae, one male and one female, occur, these series overlap very considerably and it is only towards the maximum and minimum of the range that larvae are respectively entirely female or male.

It is shown that the five larval instars of *B. tachardiae* may be grouped by the widths of the head-capsule, and that an instar can be characterised by the head-width, particularly if only averages are considered. The actual range of head-width in each instar is rather large, and in some cases the extremes overlap. In actual practice head-width is a safe indication of the instar of a larva as the extremes rarely occur; the widths calculated on Dyar's principle also approximate sufficiently closely to the observed widths to preclude the chance of an ecdysis having been overlooked.

The length of the mandible is for practical purposes identical in a larva of any given instar and in its exuviae. The larval instars and their exuviae can be grouped by the lengths of the mandibles, particularly if averages are considered; the range for a given instar is wide but the extremes do not overlap. The lengths calculated on Dyar's head-width principle approximate closely with the observed lengths, sufficiently so to preclude the possibility of overlooking an ecdysis, and making possible the identification of the instar of fixed and mounted specimens of larvae or exuviae, for which purpose head-width is useless.

The factors of increase of head-width and mandibular length are fairly similar, falling near to $\sqrt[3]{2} = 1.26$, and for practical purposes one may be substituted for the other, the calculated widths and lengths so obtained still approximating to the observed widths and lengths.

Various uses of this fact are indicated. Preliminary investigations point to the fact that similar observations apply to *Aphrastobracon flavipennis*, Ashm., an ectoparasite of *Eublemma scitula*, Ramb. It is suggested that similar observations may be true for other ectoparasitic Braconids.

The growth of the body of the larva from instar to instar is independent of the growth of the head-capsule, larvae increasing in weight and in volume by a figure lying between 3 and 4 times from instar to instar. The actual figure obtained theoretically for volume increase was 3.6. The head-size increases by the usual double at each moult.

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THE ALIMENTARY CANAL, ITS APPENDAGES, SALIVARY GLANDS
AND THE NERVOUS SYSTEM OF THE ADULT FEMALE LAC INSECT,
LACCIFER LACCA, KERR (COCCIDAE).

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(PLATES XVIII-XXI.)

The external anatomy of the female lac insect, *Laccifer lacca*, has been studied by a number of workers, but few have so far touched the internal anatomy. There appears, however, to be some confusion regarding the digestive and nervous systems, and it therefore seems desirable to give a brief description of each of them.

In the first place, it is necessary to explain that owing to the deposition of resin, the shape of the adult female lac insect either takes the form shown in fig. 1, a,

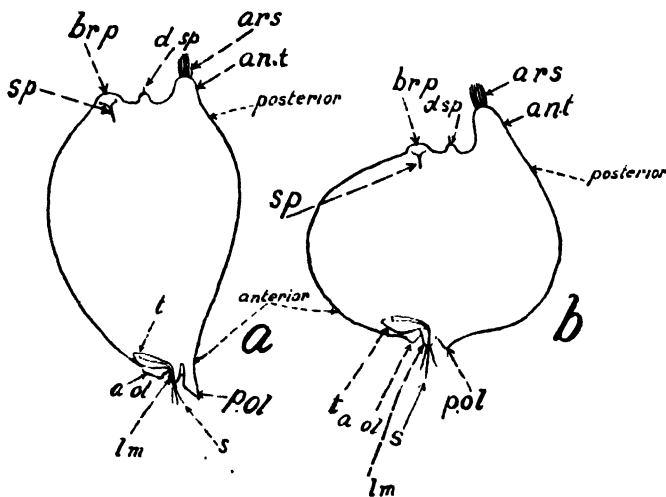


Fig. 1. *Laccifer lacca*: a, shape of adult females which grow close together and overlap one another (lac test removed); b, shape of adult females which grow more or less separately (lac test removed).

or that in fig. 1, b. The latter represents the shape of those insects which grow more or less separately without coming into very close contact with one another. The former shape is assumed by insects which coalesce or overlap.

In the females of the type shown in fig. 1, b, the rostrum (*lm*) is situated ventrally at about the middle of the insect, whereas in those of the other type shown it is situated at the extreme anterior end. In the females of the intermediate shapes the rostrum lies ventrally in the anterior half of the body.

Furthermore, it is necessary to mention that the mouth-parts in the larva of the lac insect lie on the posterior part of the ventral aspect of the head, being directed posteriorly, and the rostrum lies towards the anal extremity, as shown by Negi (1929, fig. 4, a). In the process of metamorphosis, the female lac insect loses segmentation and apparently (though the head is not differentiated from the thorax) the

direction of the mouth-parts and tentorium in the female lac insects of the type of fig. 1, b remains the same as in the larva (Pl. xviii, a); therefore, even in the cleared specimens of this type of females the rostrum is not visible from the dorsal side. In such females the rostrum (fig. 1, b; Pl. xviii, c: *lm*) lies almost at a right angle to other mouth-parts and the crumena (Pl. xviii, a, c: *cr*) lies opposite to the tentorium and the mouth-parts enclosed in it. But in the females of the type represented by fig. 1 a, the direction of the tentorium and the mouth-parts enclosed in it is totally changed; the hind end of the tentorium is directed towards the anal end of the female and the rostrum lies in front of the tentorium at an obtuse angle (fig. 1, a; *lm*, *t*) and the crumena lies over the tentorium (Pl. xviii, b: *cr*, *t*).

In either type of females the rostrum (labium) lies outside the body cavity and is situated medially between the anterior pair of oral lobes (figs. 1, a, 1, b and Pl. xviii, a, b; *aol*) and a little behind the concave facets (Pl. xviii, a: *cf*). The presence of the anterior oral lobes and of the concave facets does not seem to have been noticed by other workers on the lac insects. They were figured for the first time by Negi (1929, fig. 6, b, c). The rostrum is roughly heart-shaped, 0.1 mm. in length, and consists of one segment. The crumena is bent and measures about 0.58 mm. in length. Further description of the mouth-parts, tentorium and their homology and function has no bearing on the subject matter of the paper.

The Alimentary Canal, its Appendages and Salivary Glands.

The rostralis (Pl. xviii, a, b, c: *s*) of the female opens into the pharynx (*p*). The pharynx lies within the tentorium and is heavily chitinised, gradually increasing in diameter towards the posterior end. It is about 0.16 mm. long and about 0.02 mm. in diameter at its widest. In no specimen are the salivary glands attached to the pharynx.

The salivary glands, shaped like a bunch of grapes (Pl. xix, a, b, c: *sg*) with their common duct lie on either side of the oesophagus, not in close proximity with it but with the ventral ganglion (Pl. xix, b: *sg*, *vg*) which lies below the oesophagus and is connected with the ventral skin of the insect by the nerves, while the oesophagus is free. Each bunch of the salivary glands consists of ovoid and spherical bodies, the ducts of which join to form a common duct (*cd*) on each side. The common duct of each side runs close to the consolidated ventral ganglion and passes under it to unite near its anterior end. The terminal duct (*td*) so formed opens into the pharynx within the tentorium.

The pharynx continues into the elongated oesophagus (Pls. xviii and xix, a, b: *oes*), which is 0.6–0.8 mm. in length and about 0.02 mm. in diameter, and passes into the colo-rectum to be succeeded by the convoluted ventriculus (Pls. xix, a, b, e; xx, c; xxi, a: *v*). The ventriculus on leaving the colo-rectum leads into the intestine (*mi*, *hi*). The part of the intestine from the ventriculus to the point where the ampulla or bladder of the Malpighian tubes joins it is the mid-intestine and the remaining part the hind intestine. The intestine after encircling the greater part of the colo-rectum re-enters it (Pls. xix, e and xx, b) close to the point of its commencement from it. The hind intestine does not end here but continues closely attached to the outer side of the ventriculus from its distal to its proximal end (Pls. xix, e; xx; xxi, a). After this it leaves the colo-rectum near its proximal end (Pls. xix, e; xx, a, d) and runs by its side to open finally into it at a point about the anterior third of its length (Pl. xix, a, b, e). The colo-rectum opens at the anus (*a*) situated at the posterior end of the insect and surrounded by the anal ring plates. The length of the mid-intestine varies from 5.4–10 mm., and of the hind intestine (from the opening of the Malpighian ampulla to the opening of the intestine into the colo-rectum) 2.9–3.6 mm. The length of the colo-rectum is about 3.5 mm. The part of the colo-rectum anterior

to the opening of the intestine into it is the colon and the part posterior to it is the rectum.

Actually, the hind intestine passes close to the origin of the mid-intestine and the adjacent walls of the hind and mid-intestine become confluent at the top of the colo-rectum. The shape assumed by the two abutting intestines at the point of confluence depends on the manner in which the convolutions of the ventriculus and of the portion of the hind intestine inside the colo-rectum are deposited at the time of fixation. The hind intestine, however, enters the colo-rectum outer to the mid intestine and the opening of the ventriculus into it and runs closely attached to the ventriculus from its distal to its proximal end (Pls. xix, e; xx; xxi, a). After this, it emerges out of the colo-rectum and finally opens into the colo-rectum as stated above. Owing to the flattening of the hind intestine, its close attachment to the ventriculus throughout its course, and their combined convolutions, it is not easy to differentiate them in *in situ* mounts or in sections, unless carefully prepared and stained mounts and serial transverse and longitudinal sections are studied. Both in the mounts and sections the ventriculus takes less stain than the part of the hind intestine running outside it. The structure of the walls of the part of the hind intestine inside the colo-rectum and running beside it is the same as that of the part lying between the colo-rectum and the ampulla of the Malpighian tubes and not approaching to that of the rectum, as described by Hough (1925) in the case of the intestinal duct of *Trionymus trifolii*.

The diversity of opinion among various workers has been mainly about the convolutions inside the colo-rectum, which some have considered to be an internal gland and others the ventriculus. The part of the alimentary canal called the "colon caecum" has also been little studied. Berlese (1906) has illustrated two forms of alimentary canal in COCCIDAE in figures 911 (I) and 911 (II). In both the figures the ventriculus which he calls "ansa del pro-intestino" forms the convolutions inside the colo-rectum; these convolutions have been referred to by some workers as an internal gland. Berlese in his figure 911 (I) has shown that the intestine after originating from the ventriculus again meets the colo-rectum near the latter's proximal end on the side opposite to its own origin, and from this point onwards the intestine narrows in calibre and ultimately opens into the colo-rectum; he calls this part of the intestine "tubolo tra questo ed il retto"; while his figure 911 (II) shows the intestine re-entering the colo-rectum and ending blindly round the ventriculus and this part of the intestine he calls "ansa dell'intestino." In *Trionymus trifolii*, Hough found the stomach coiling on itself in the rectum, but does not find the intestine re-entering the so-called rectum to form convolutions along with the stomach. In the case of the female lac insect, I find that though the oesophagus, as illustrated by Berlese, passes into the colo-rectum to form the ventriculus, which after emerging out of the colo-rectum leads into the intestine, and the latter re-enters the colo-rectum as in Berlese's figure 911 (II), but unlike his illustration the intestine does so close to the point of its origin from the ventriculus. It also does not end blindly surrounding the ventriculus but forms a sort of outer lining to the ventriculus and emerges from the colo-rectum from the end where the oesophagus enters it to open ultimately into the colo-rectum at about one-third of its length. The convolutions formed inside the colo-rectum are thus comprised not only of ventriculus, as illustrated by Berlese and recently pointed out by Hough and Misra, but also of the part of the hind intestine running outer to it. The "colon caecum" is absent and the part labelled so by Misra in his drawings is the posterior part of the hind intestine itself, and its cellular structure is the same as that of its anterior part and does not approach to that of the rectum as described by Hough in *T. trifolii*.

The pair of Malpighian tubes (Pl. xix, a, b, e: *mt*) open into the intestine by a common ampulla or bladder (*am*) almost level with the ventriculus. In both types of female the free ends of the Malpighian tubes are directed towards the aboral

end of the insect. However, in a few females of the type of fig. 1, a, or females approaching this type, the posterior portions of the Malpighian tubes are found recurved towards the oral end.

The Nervous System.

Prior to the description of the nervous system, it is necessary to point out the relative positions of the mouth-parts, the cerebral (supra-oesophageal) and the consolidated ventral ganglion. In the type of the females represented by fig. 1, b, the cerebral ganglion lies anterior to the mouth-parts and the ventral ganglion over them (Pl. xviii, a : *cg*, *vg*), but in the females of the shape of fig. 1, a, the cerebral ganglion lies either lateral to the mouth-parts or partly under them, and the ventral ganglion posteriorly at the hind end of the mouth-parts.

The general shape of the cerebral and ventral ganglia of the females in which the cerebral ganglion lies anterior to the mouth-parts and the ventral ganglion over them is shown in Pls. xix, b and xxi, b, c, and of the females in which the former lies either lateral to the mouth-parts or under them and the latter posterior to them is shown in Pl. xix, a and xxi, d. Both the ganglia, however, vary greatly in shape in different specimens of either type of females.

The cerebral ganglion (Pl. xxi, b, d : *cg*) consists of two lobes. From the anterior region two pairs of nerves arise, the inner nerve of each pair (Pl. xxi, b : *an*) supplies the vestigial antennae, and the outer (Pl. xxi, b : *lgn*) the anterior marginal and ventral glands. From the posterior region arise two connectives (Pl. xxi, b, d, h : *con*), which pass backwards between the *arcus superior* and *arcus inferior* (Pl. xviii, a : *con*) and meet the club-shaped ventral ganglion (Pl. xxi, b, h : *vg*). Transverse sections show longitudinal division in the ventral ganglion, which gives off five pairs of nerves. The first three pairs of the nerves (Pl. xxi, b : *mpn*) supply the mouth-parts and the glands in this region. The fourth pair (Pl. xxi, b : *atmn*) supplies by its branches the anterior tergo-sternal muscles, the tracheae running from the posterior spiracles towards the ventral body wall, the posterior spiracles, and the anterior ramifications of the ovary. The fifth pair of nerves runs to the anterior and posterior spiracles. The ventral ganglion after this is followed by the nerve chord (Pl. xxi, b, d : *vn*), which is always longer in the females represented by fig. 1, a, than in the other form. Even in the latter there is variation in the length of the nerve chord ; in some of them the chord is so reduced in length as to be almost indistinguishable, with the result that the intestinal nerve and the two main branches of the nerve chord appear to arise from the ventral ganglion itself. The nerve chord after running a short distance gives off a nerve to the intestine (Pl. xxi, b : *in*). This nerve in its turn divides and subdivides to supply the colo-rectum and the mid and hind intestine. A short distance from this point the nerve chord breaks up into two main branches. The nerve (*min*) of each branch supplies the Malpighian tube of its side and the third and fourth nerve (*on*) supplies the ovary and the lac glands, etc. ; each branch then runs inner to the oviduct of its side and divides into two, the inner divisions (*antn*) supply the vagina and enter the anal tubercle, and the outer (*ptmn*) supply the posterior tergo-sternal muscles, prevaginal glands and other lac and wax secreting glands of their side.

There is a certain amount of variation in the number of nerves given off by the nerve chord before it divides into two. In some individuals a nerve may precede the intestinal nerve, and another nerve may arise opposite to the intestinal one. The intestinal nerve may divide into two main branches soon after its origin from the nerve chord.

In the adult female lac insect, owing to the ramifications of the ovary and tracheae and the type of muscular system, it is rather difficult to trace the distribution of the

branches and sub-branches of the nerves. I hope, therefore, to make the description of the entire nervous system more complete and detailed at some future date by studying the system in the young female lac insect and its larval stages.

I wish to express my thanks to Dr. C. F. C. Beeson, the Forest Entomologist, Dehra Dun, and to Mr. P. M. Glover, the Entomologist at the Institute, for criticisms on the manuscript of the paper, and to Mr. E. Heber the artist for drawing the illustrations.

Summary.

Owing to the deposition of resin, the females assume two shapes, one somewhat circular in which the mouth-parts are situated ventrally about the middle of the body, and the other pyriform, in which the mouth-parts are situated at the extreme anterior end. In the former type of females the mouth-parts are posteriorly directed and in the latter anteriorly. The rostrum lies outside the body cavity between the anterior pair of oral lobes. The rostralis opens into the pharynx which lies in the tentorium. The oesophagus is elongated and passes into the colo-rectum to be succeeded by the convoluted ventriculus. The ventriculus on leaving the colo-rectum leads into the intestine, which is marked into the mid and hind intestine by the junction of the ampulla of the Malpighian tubes. The intestine after forming a loop round the greater part of the colo-rectum re-enters it close to the point of its commencement from it and continues closely attached to the outer side of the ventriculus from its distal to its proximal end; after this it comes out of the colo-rectum and runs alongside it to open into it near the anterior third of its length. The convolutions inside the colo-rectum are comprised of the ventriculus and the part of the hind intestine running outer to it. The "colon caecum" is absent. The colo-rectum opens at the anus situated at the posterior end of the insect and is divided into colon and rectum by the opening of the intestine into it.

The salivary glands consist of two branches of ovoid and spherical bodies. The common duct of the salivary gland of each side runs close to the ventral ganglion and joins the opposite duct to form the terminal duct near its anterior end, which then opens into the pharynx.

The nervous system consists of a bilobed cerebral ganglion which lies anteriorly to the mouth-parts in females in which the tentorium is directed posteriorly, and either laterally or ventrally to it in females in which the tentorium is directed anteriorly and lies at the extreme anterior end. The cerebral ganglion is joined by a pair of connectives to the ventral ganglion, which lies dorsal to the tentorium in females in which it is directed posteriorly, and posterior to the tentorium in which it is directed anteriorly and lies at the extreme anterior end. The ventral ganglion is followed by the nerve chord, which varies in length in either type of female. The main nerves arising from the central nervous system are described.

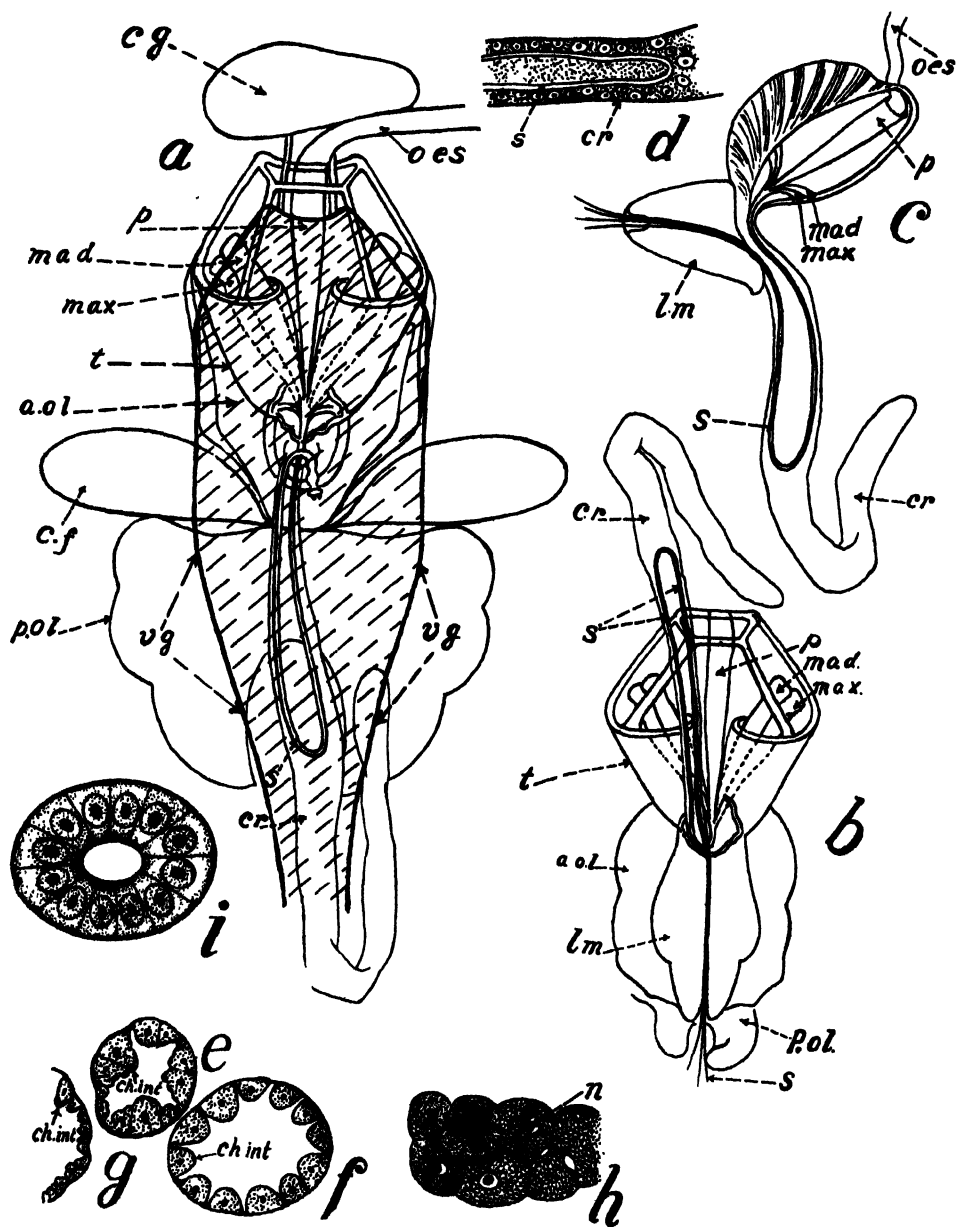
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KEY TO LETTERING.

<i>a</i>	anus	<i>max</i>	maxilla
<i>am</i>	ampulla or bladder	<i>mi</i>	mid intestine
<i>an</i>	antennary nerve	<i>mpn</i>	nerves to mouth-parts and glands
<i>ant</i>	anal tubercle		near them
<i>antn</i>	anal tubercular nerve	<i>mt</i>	malpighian tube
<i>aol</i>	anterior oral lobe	<i>min</i>	malpighian nerve
<i>ars</i>	anal ring setae	<i>n</i>	nucleus
<i>atmn</i>	anterior tergo-sternal muscle nerve	<i>oes</i>	oesophagus
<i>bm</i>	basement membrane	<i>on</i>	ovarian nerve
<i>brp</i>	brachial plate	<i>ovmi</i>	opening of ventriculus into mid
<i>c</i>	colo-rectum		intestine
<i>cd</i>	common duct	<i>phs</i>	arcus superior
<i>cf</i>	concave facets	<i>pol</i>	posterior oral lobe
<i>cg</i>	cerebral ganglion	<i>ptmn</i>	posterior tergo-sternal muscle
<i>chint</i>	chitinous intima		nerve
<i>con</i>	connectives (crura cerebri)	<i>r</i>	rectum
<i>cr</i>	crumena	<i>s</i>	rostralis
<i>cu</i>	cuticle	<i>sg</i>	salivary glands
<i>dsp</i>	dorsal spine	<i>sp</i>	spiracle
<i>hi</i>	hind intestine	<i>t</i>	tentorium
<i>hyp</i>	hypodermis	<i>td</i>	terminal duct
<i>in</i>	intestinal nerve	<i>tn</i>	trachial nerve
<i>lgn</i>	anterior marginal and ventral	<i>v</i>	ventriculus
	gland nerve	<i>vhi</i>	ventriculus and hind intestine
<i>lm</i>	rostrum (labium)	<i>vg</i>	ventral ganglion
<i>mad</i>	mandible	<i>vn</i>	ventral nerve chord



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Details of *Laccifer lacca*, Kerr.

EXPLANATION OF PLATE XVIII.

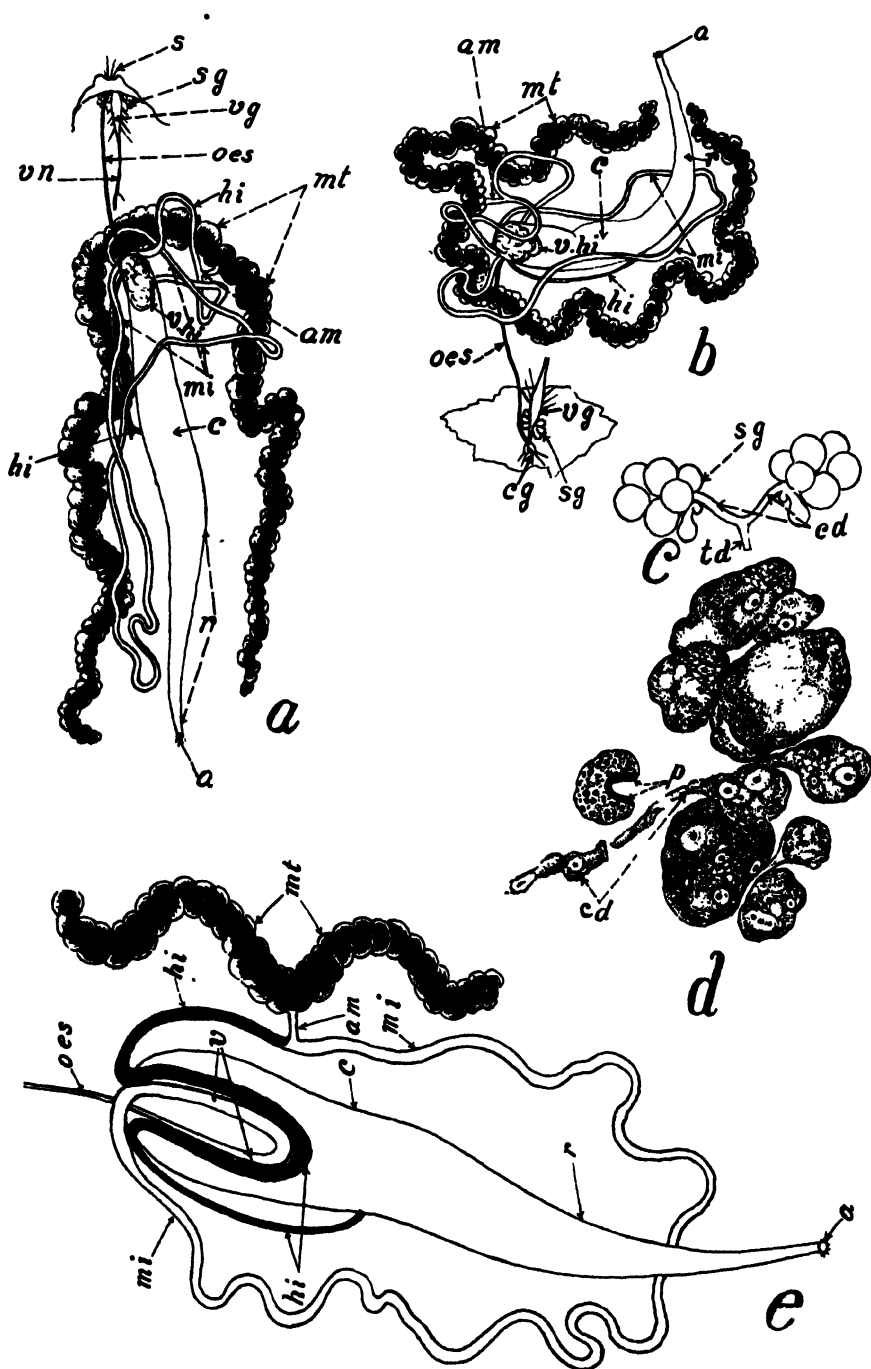
Laccifer lacca, Kerr

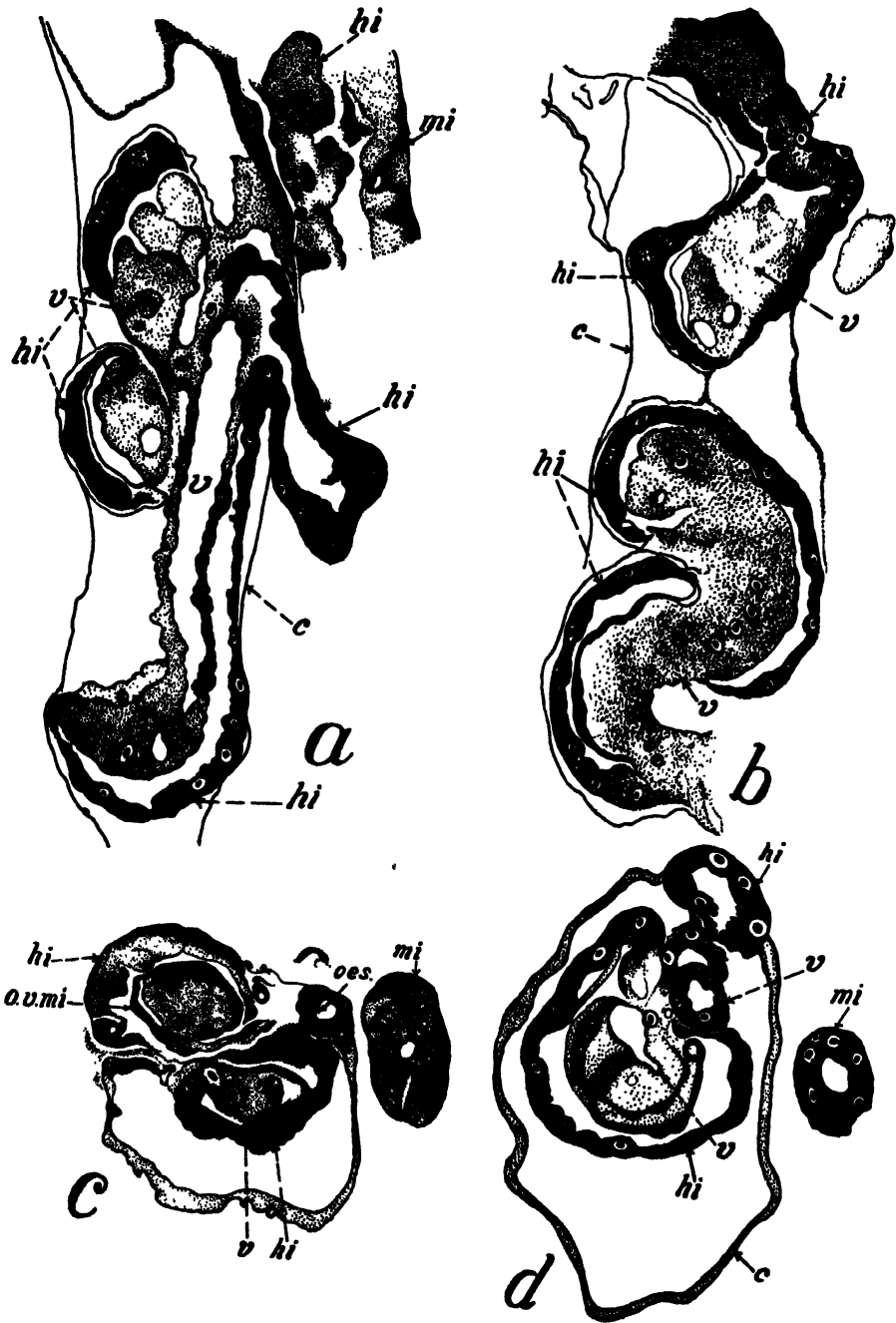
- a. Dorsal view of mouth-parts and oral lobes of females represented by text-fig. 1 b, showing the crumena lying opposite the tentorium, and the relative position of the mouth-parts and the cerebral and ventral ganglia in such females.
- b. Dorsal view of mouth-parts and oral lobes of female represented by text-fig. 1 a, showing the crumena lying over the tentorium and the rostrum in front.
- c. Lateral view of tentorium and mouth-parts of females represented by text-fig. 1 b, showing the rostrum lying almost at right angles to the tentorium.
- d. Longitudinal section of crumena showing its cellular structure.
- e. Transverse section of mid intestine.
- f. Transverse section of hind intestine.
- g. Transverse section of colo-rectum.
- h. Longitudinal section of Malpighian tube.
- i. Transverse section of oesophagus.

EXPLANATION OF PLATE XIX.

Laccifer lacca, Kerr

- a. Dorsal view of the alimentary canal and its appendages, etc., of the type of female in text-fig. 1 a.
- b. Dorso-lateral view of the alimentary canal and its appendages, etc., of the type of female in text-fig. 1 a.
- c. Salivary glands with their common and terminal duct.
- d. Longitudinal section of the salivary glands.
- e. Diagrammatic figure of the alimentary canal showing relative position of its different parts.





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Details of *Laccifer lacca*, Kerr.

EXPLANATION OF PLATE XX.

Laccifer lacca, Kerr

Camera lucida drawings :—

Figs. a, b, longitudinal sections of alimentary canal.

Figs. c, d, transverse sections of alimentary canal.

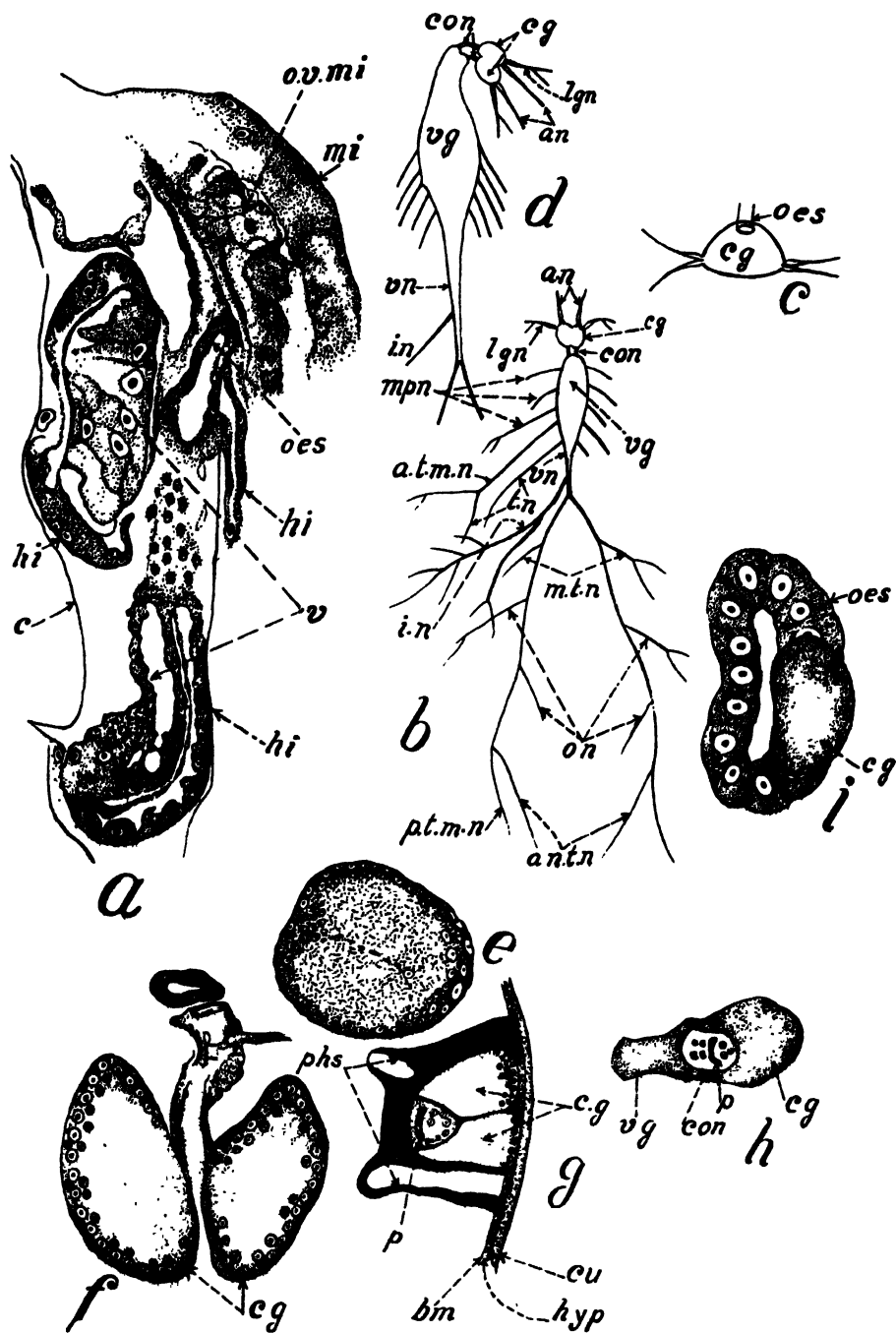
In the material for figures c and d the last portion of the hind intestine lying alongside the colo-rectum was removed from close to its origin from the colo-rectum before it was embedded for sectioning.

- a. Showing hind intestine emerging out of colo-rectum.
- b. Showing hind intestine distinctly entering the colo-rectum.
- c. Showing oesophagus entering colo-rectum; ventriculus and hind intestine inside colo-rectum.
- d. Showing hind intestine emerging out of colo-rectum.

EXPLANATION OF PLATE XXI.

Laccifer lacca, Kerr

- a. Longitudinal section of alimentary canal showing oesophagus, ventriculus and hind intestine inside colo-rectum and opening of ventriculus into mid intestine outside it.
- b. Nervous system of the females of the type of text-fig. 1 b.
- c. Dorsal view ; shape of cerebral ganglion of some of the females of the type of text-fig. 1 b.
- d. Anterior part of the nervous system of the females of the type of text-fig. 1 a.
- e. Transverse section passing through the middle of the cerebral ganglion.
- f. Transverse section of the cerebral ganglion near its posterior end showing its bilobed nature.
- g. Transverse section of the tentorium showing the cerebral ganglion passing down between the *arcus superior*.
- h. Longitudinal section of the cerebral and ventral ganglion showing them joined by connectives.
- i. Transverse section of the region immediately behind the tentorium, showing a portion of the cerebral ganglion lying over the oesophagus.



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Details of *Laccifer lacca*, Kerr.

flying long distances into cities and towns for the purpose of obtaining meals of blood. Regarding such species he later goes on to say : " It is, of course, very unfortunate that after the elimination of all breeding-places in a selected area the migratory species of mosquitos may at any time become so prevalent as to make the inhabitants believe that nothing has been accomplished, and that the public money is being wasted upon a hopeless task." But, in my experience, these three species are so much less vicious biters than *fatigans* that, though the public, after an extended period of virtually complete freedom from mosquitos, will notice such an influx, yet if their numbers be kept within bounds by control of breeding within the usual $\frac{1}{2}$ - $\frac{3}{4}$ mile circle, no complaints will arise. It is far otherwise if *C. sitiens*, as in Colombo, forms part of the invasion.

The extent to which mosquitos are prevalent in better-class houses is largely ruled by two factors, elevation and presence or otherwise of curtains and other hangings, though the first factor does not apply to peri-domestic breeders like *Stegomyia*. An instructive instance of this was obtained by the writer in 1926 in the block of railway officers' flats where he himself resides. These flats are three-storied,

TABLE VI.

Mosquitos caught in a thorough search of all rooms in Nos. 1-6, Godfrey Mansions, B.-N. Railway, on 29.vii.1926 M- married, B = bachelor, establishment.

			<i>A. vagus</i>	<i>C. fatigans</i>	<i>S. vishnu</i> and <i>tritacanthochus</i>	<i>C. gelidus</i>	<i>S. fasciata</i>	<i>M. annuliferus</i>	Total	% of grand total	
No. 6	...	M	—	4	8	—	5	1	18	25	} Top storey
No. 5	...	B	—	—	1	—	—	—	1		
No. 4	...	M	6	4	5	—	3	—	18	34	} Middle storey
No. 3	...	B	—	2	1	1	4	—	8		
No. 2	...	B	1	—	2	—	1	—	4	41	} Ground storey
No. 1	...	M	2	8	16	—	1	—	27		
Totals	...	...	9	18	33	1	14	1	76		
Percent. of total			11	24	43	1	19	1			

two flats to a storey, and on the occasion on which the observation tabulated below was made, it so happened that one flat of each storey was inhabited by a married couple, the other by a bachelor. It is unnecessary to dilate on the difference this means in curtains, cushions, valances to arm-chairs and settees, and clothes hanging in almirahs. The observation was made in July 1926, before there was any control at Garden Reach, and was carried out in an attempt to collect all specimens of *Stegomyia* that might have bitten the first dengue case of the season in the railway colony before the insects became infective for others.

The progressive decrease in mosquito population as each storey's height is gained is well brought out, and the percentage figures are not appreciably altered if

Stegomyia is deducted from the totals. Of the catch 80 per cent. was in the married flats. *Stegomyia* is seen to be unaffected by elevation.

At the end of Tables I-III will be noticed a column "density per catching minute." The reason for its insertion is that, in my experience, complaints (from Europeans) about mosquitos (other than *Stegomyia*) are not received until this figure reaches about 0.67. In Garden Reach this means that there is only a mosquito nuisance between December and March (or April). At this time of year the only prevalent mosquito is *Culex fatigans*, which plays so large a part in the general economy of mosquito work in the City of Calcutta that considerable attention has been paid to its bionomics, the results of which form Part 2 of the present paper.

2. The Bionomics of *Culex fatigans*.

As shown in the first part of this paper, *Culex fatigans* is the predominant mosquito of Garden Reach, as of Calcutta generally. In the third year of control it still forms 65 per cent. of the total mosquito catch. It, and it alone, is responsible for the annual winter mosquito plague, and at a season when all other mosquitos sink into insignificance, *fatigans* increases enormously, and, as Table VIII shows, two-thirds of the annual catch of this species is made in the four months January to April.

There is a considerable literature on *fatigans*, which I have consulted, at least in abstract, from 1919 onwards, and it is obvious that a vast amount of work still requires to be done before anything that can be called an adequate knowledge of the bionomics of this species is available. Before giving the results of my own work here, what is already known may be summarised.

1. Breeding Requirements.

Almost any water, however foul, will serve for *fatigans* in this respect, provided that the current is not so swift as to wash the larvae away. King (1929) and his collaborators state that the chief breeding-grounds in Madras are small cement pits to catch sillage and sewage, which are *supposed* to be emptied daily. That these are important breeding-grounds no one will deny, but compared with other types they are frequently of relatively small extent, though their output may be enormous. Further, with the complete lack of efficiency that usually characterises the conservancy arrangements of the average Indian Local Authority, they frequently become so foul that *fatigans* will not breed in them, its place being taken by an undetermined Ephydrid fly that will tolerate much higher degrees of pollution, including a soupy mass of raw faeces that, in my experience, *fatigans* avoids. Korke (1930b) directs attention to another very important type of breeding-place, as entirely man-made as that referred to by King, which is usually the product of the poor and cheap sanitary engineering so common in this country, namely the junction of a cement drain with an earth drain leading away from the end of the former. The filthy puddle forming at this point frequently produces *fatigans* in enormous numbers. Tables III-V in Paiva (1912) show that a very high proportion of the total breeding of this species occurs in Calcutta in open drains, which still occupy the foremost place in production, even in the rains.

From such foulnesses *Culex fatigans* can pass to tolerate clean water of the degree found in drinking tanks. Bodkin (1921) in British Guiana and Hill (1922) in Australia, note its fondness for rain-water containers and fresh-water tanks respectively, and I have bred it from drinking-water tanks on steamers in the Port of Calcutta. But for all this apparent catholicity of taste there are certainly hydro-chemical factors that strongly influence breeding. Hydrogen-ion concentration affords at least a measure of the interplay of some of these.

Considerable work on the pH requirements of *fatigans* has been done by Hamlyn-Harris. In his first paper (1927) he declares the species to be an acidophile and states that it becomes associated with *Stegomyia fasciata* when the water in which this is living reaches pH 6.5. In his next two papers (1928 a, b) he gives as toleration limits (in the presence of abundant food only) pH 6.6-8.6. At pH 6.2 and 9.1 eggs hatched, but the larvae died shortly afterwards. In his fourth paper (1930) he finds acidity fatal. The optimum is pH 7.4 to 8.6, and though larvae hatched and at first grew at pH 5.0 and 5.4, they thereafter died.* MacGregor (1924), however, states that *fatigans* is distinctly an acidophile with occasional excursions into alkalinity. My own work (Senior White, 1926) indicates it as an absolute alkaliphile, tolerating pH up to 9.6, whilst Buxton (1927) found it equally present and absent at all values between pH 7.0 and 8.2, and outside this range he encountered no apparently suitable water.†

Morishita (1925) gives pH 6.5-7.6 as its limits in Formosa. Patterson (1926) definitely states that *fatigans* is an alkaliphile, but the chemicals which she used experimentally to alter her pH values are many of them definite larval poisons; so I do not think her results can be used in establishing concentration limits.

Nothing definite emerges from such conflicting evidence, save that certainly the species is as much an alkali- as an acido-phile.

Apart from pH, Hamlyn-Harris (1930) has also worked on the effect on the larvae of the various chemical combinations occurring during the nitrogen cycle, and compares those with the analysis of a flourishing *fatigans* breeding-place. As he says, no other mosquito, except *Lutzia* (and in this country *Armigeres*), could possibly exist in such concentrations. As this paper is not very accessible the analysis is repeated here, being, I think, the only one yet made on the water requirements of *fatigans*, and so very useful for comparison to anyone doing similar work in this country.

Parts per Million.

Free ammonia	...	...	...	...	25.75
Albuminoid ammonia	...	...	...	...	25.5
Nitrites	...	...	...	...	0.0025
Nitrate	...	...	...	...	0.6
Chloride	...	...	...	...	220.0
Total alkalinity	...	...	...	...	820.0
Consumed oxygen at 212 in 30'	...	...	...	...	370.0
pH	...	...	...	...	7.5

Sharma & Sen (1921) published some preliminary experiments on the factors influencing oviposition in various mosquitos, including *C. fatigans*, but nothing very definite emerges from their results, save that when water of three temperatures between 23°C. and 35°C. was offered, oviposition always occurred in the hottest of the three. Buxton (1927) draws attention to the adverse effects on oviposition of rain about twilight, his experimental pots being infected in dry weather only. This may be a contributory cause in the relative paucity of this species during the rains.

*Hamlyn-Harris obtained his acidity by adding banana to the breeding water. Now this is precisely the pabulum which Siler, Hall, and Hichens (1926) found most suitable for raising the large broods of adults required for their experiments on the transmission of dengue, and there is nothing in either paper which will explain the diametrically opposite results arrived at.

†In January 1934 larvae and pupae were found by my staff in a tank of dilute HCl in a paint and varnish works. The pH was actually about 1.6.

2. Duration of the various Stages.

According to Siler, Hall & Hichens (1926) a newly engorged female oviposits on the 4th or 5th day following. Pomeroy (1920) states that the minimum time for eggs to hatch is under 24 hours, for larvae to complete their development under 120 hours, and for the pupal stage under 48 hours. Buxton (1927) gives 24–48 hours for this last. Therefore a generation is gone through in under 192 hours (8 days). Hamlyn-Harris (1930) states that at mid-winter in Brisbane (temp. 73°–65°F.) seventeen days are taken from oviposition to the first male emergence. This is a lower maximum than is ever reached in Calcutta, though here the minima are for three months considerably lower (*vide* Table VII). Barber (1928) gives 2–3 days as a general interval from oviposition to hatching. He states that oxygen is essential, but there is no indication that hatching is prompted by bacteria.

3. Food of the Larva.

Barber (1927) states that he reared *C. fatigans* to maturity on a culture of mixed bacteria. The same author (Barber, 1928) states that living organisms seem essential for any considerable development. Adults were raised from pure cultures of yeast, bacteria and the green alga *Scenedesmus*. Its habit of breeding in hay infusions, etc., is common knowledge. Hinman (1932a) states that larvae can utilise the non-dialysable fraction of water from their breeding pools. But both Barber and Hinman state that no progress in growth is made in sterile media, though the larvae can subsist for 10–12 days in these circumstances, indicating that they must derive some nourishment from the media. Hinman (1932b, 1933) investigated the enzymes in the alimentary tract and has found amylase, invertase (sucrase), xylanase and a protease acting in alkaline media, and suspects the presence of a lipase. Maltase, lactase and a protease acting in acid media were absent.

Siler, Hall & Hichens (1926) state that males emerge first, but under adverse conditions females only emerge, the larvae of that sex being hardier, though those of the male are more precocious. The freshly emerged female normally lives one, and can live two days, without food or water.

4. Bionomics of the Adult.

Two papers, which I have been unable to consult in the original, Dyar (1921) and Pinto (1923), deal with the swarming habits of the males round human beings at dusk and the copulatory act respectively. The biting reflex has been studied by Marchand (1918), by workers in Malaya (Kingsbury, 1932), and by Bruce Mayne (1930). The first worker endeavoured to analyse the factors causing the reflex. He failed to do this, but found that shed blood and perspiration had no more attraction for females than had water. The Malayan workers found that, compared with various *Anopheles*, *C. fatigans* is not at all voracious. The percentage of various species feeding on monkeys was found to be :—

<i>Anopheles maculatus</i>	...	...	...	...	89
<i>Anopheles vagus</i>	...	...	...	...	42
<i>Stegomyia albopicta</i>	...	...	...	...	62
<i>Armigeres obturbans</i>	...	...	...	...	38
<i>Culex fatigans</i>	...	...	...	...	18

but the meteorological conditions under which these experiments were carried out are not stated.* In the light of the third author's work these are very important. Mayne (*loc. cit.*) gives a table of percentage of *fatigans* feeding at various humidities, but far more can be learned from this table if its data are transposed into saturation

*Taking the meteorological figures for Kuala Lumpur given in the report of the Health Officer (unpublished, official document) for 1931, the saturation deficiency must have been between 2 and 5 mm., i.e., below the optimum for biting in *Culex fatigans*.

deficiencies, which Buxton (1931, 1933) has since shown to be a far better measure of the effects of climate on an insect. When Mayne's table is thus recast the results are :—

R.H.	S.D.	Per cent. fed
49	17.5	0
50	18.0	0
{ 52	20.0	0
{ 52	20.0	1
58.5	15.0	4
74.0	9.0	43
81.0	6.0	77
84.0	5.5	76
93.0	2.5	57
97.0	1.0	61

The extreme importance of these results will be seen when we come to examine the influence of climate on the bionomics of the insect in Calcutta. But once on the wing, and fed, *Culex fatigans* appears to be a far from hardy species, far more susceptible to climatic vagaries than would at first sight seem probable for such a common and cosmopolitan species. Siler, Hall & Hichens (1926), after stating that a newly fed female oviposits on the 4th or 5th day following, state that she then frequently dies. In the dry season (March) in the Philippines, eleven out of twelve specimens died before laying occurred; 21 per cent. of those that fed in the course of their experiments died by the 12th day, and of those remaining only 30 per cent. would feed twice. Mortality becomes very high after the second and third feed, though Taylor (1928) states that *fatigans* may oviposit no less than five times. According to the Philippine workers the natural span of life is 2-3 weeks. Rao & Iyengar (1930) draw attention to the very heavy mortality that occurs in Calcutta (in cages), in all months between December and June.* Now December (or January) is the coolest and most humid, and April the hottest and driest month of the year, as Table VII shows.

Bruce Mayne (1930) investigated the thermal death point of the adults. His results are :—

Temperature °F.	R.H.	S.D.	Life
113	56	mm. 36	Less than 1 minute
104-107.6	55-57	30-31	1-3 hours
96	42-43	29	2-3 days

He states that the species will not bite at a temperature at which it cannot survive desiccation. Korke (1930a) records finding very heavy breeding in a house-drain at

*This paper contains monthly meteorological records for Calcutta for 1927 and 1928, which may be compared with records for 1931-33 given in Table VII.

the end of May, with the walls covered with adults, including many males, at a temperature of 109° and a R.H. of 19-17 per cent. (S.D. 50 mm.). Korke (1930b) records breeding in January at a temperature and humidity equivalent to an S.D. of 1.5 mm., and other observations in his two papers cover S.D.s of 6-8 mm. (December), 10.5 mm. (January), 14 mm. (February) and 15 mm. (March). There are no observations covering the period June to December, and in his first paper he assumes that the rains favour breeding, which I consider erroneous, though I am not very familiar with the central plains area of Bihar where his observations were made.

TABLE VII.

Meteorological Statistics, Alipore Observatory, Calcutta.

	1931-32				1932-33				1933-34			
	Max.	Min.	S.D.	R.F.	Max.	Min.	S.D.	R.F.	Max.	Min.	S.D.	R.F.
March ...	92	71	4.6	1.3	94	72	5.2	0.7	93	70	4.5	0.0
April ...	97	78	5.5	1.1	98	76	6.4	1.1	95	76	5.3	3.0
May ...	94	79	6.0	7.0	95	80	5.5	11.7	94	77	5.2	7.7
June ...	89	79	4.2	5.8	91	80	3.9	7.4	92	80	4.1	15.8
July ...	89	79	3.2	13.7	89	79	2.7	9.9	87	79	2.9	17.2
August ...	89	80	2.5	8.7	88	79	2.7	9.0	88	79	2.8	14.6
Sept. ...	90	79	2.4	12.7	88	79	2.6	9.5	88	78	3.1	10.5
Oct. ...	87	76	2.7	6.3	89	76	3.0	3.8	88	75	3.1	9.6
Nov. ...	82	66	1.6	5.2	82	68	2.3	9.0	84	66	3.7	0.0
Dec. ...	78	59	2.0	0.0	79	59	1.7	0.0	78	58	1.9	0.0
Jan. ...	81	59	1.2	0.0	76	54	2.3	0.8	78	55	2.5	0.0
Feb. ...	83	61	2.4	0.2	83	64	1.9	2.6	83	62	2.4	0.1
				62.0				65.5				78.5

Gill (1921) states that a temperature of 80.6°F. and a R.H. of 48 per cent. (*i.e.*, a S.D. of 13.5 mm.) is necessary if the adults are to live 5 days. Females will not feed at under 40 per cent. R.H. and feed readily at 50 per cent., which are much lower values than those found by Bruce Mayne. He gives an instance (in the Punjab) of *Culex fatigans* entering a house on a hot, dry, windless night, but normally he could clear his house of the species by opening doors and windows and turning on the verandah lights. These observations point to the female seeking the highest degree of humidity available.

Majid & Sinton (1933) had no deaths in two weeks at an estimated R.H. of 80 per cent., but at the end of 15 weeks at the same figure 54 per cent. were dead. The saturation deficiency cannot be worked out from their figures.

This is all that I have been able to find in the literature regarding the bionomics of *Culex fatigans* from egg to and through adult life. The contradictory pH observations indicate that very little is known of the exact breeding requirements, and if a sullage outfall is followed from (say) its source in a septic tank, down a nullah, it is common to find no larvae until a certain point, where the species suddenly appears in millions.

and investigations on such areas by specialists in the chemistry and bacteriology of sewage would probably teach us more than anything else regarding its breeding conditions.

An observation was made on this point when investigating an outbreak of this species at Ranchi in April 1933. The breeding was occurring in an earth drain leading from the end of a cement drain carrying sullage water. The findings are best expressed in tabular form :—

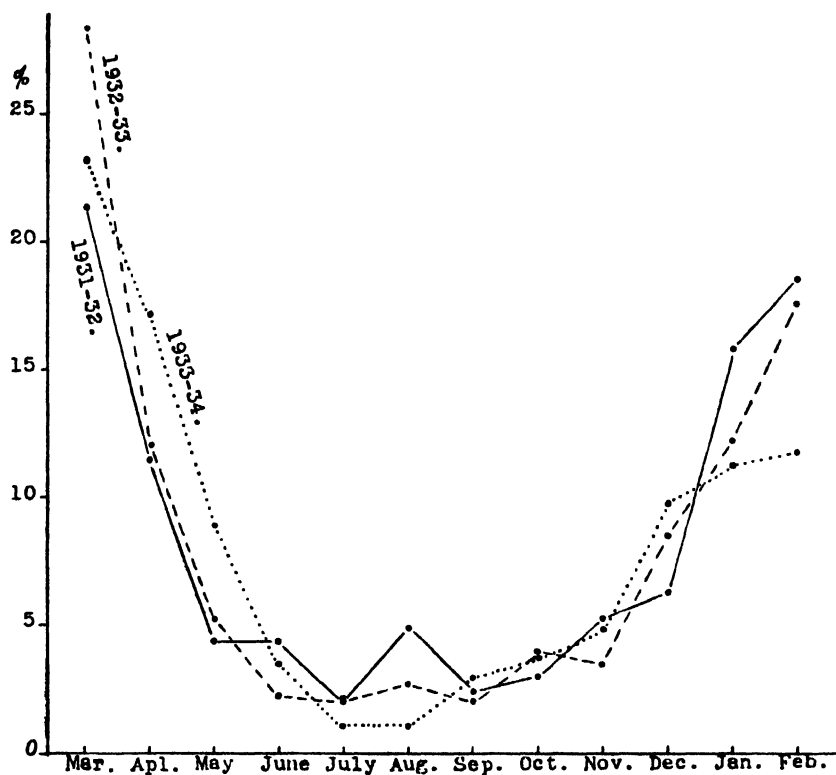
Point	Distance from previous point	Findings
	Feet	
A	0	End of cement drain ; soap striae, egg rafts ; larvae 80 per dip
B	30	Water clear, no vegetation , 18 per dip
*C	20	Block of flood-carried leaves ; 12 per dip
D	25	Flow has ceased, scum forming ; coarse grass in separated tufts ; breeding + + + +
E	40	End of + + + + breeding ; <i>Massilea</i> , which first showed 6 feet higher up, fairly common
F	17	Grass and <i>Massilea</i> , a dirty brown Cyanophyceous alga , 4 <i>Culex</i> and 1 <i>Anopheles</i> larvae per dip
G	15	A small Cyperaceous plant appears ; larvae nil
H	15	A Chlorophyceous alga (2 <i>Oedogonium</i>), grass and <i>Massilea</i> ; larvae nil
J	15	Clear puddles on mud among grass tufts ; <i>A. culicifacies</i> 5 per dip

*From point B to point C is a pipe drain under a road.

Thus in 177 feet of drain only 40 feet were breeding extremely heavily, *i.e.*, with dense black masses of larvae visible without bending down, the movements of which cause the surface of the water to " shimmer " in a peculiar fashion.

Rao & Iyengar's observations that a heavy mortality is apparently independent of the highest extremes of climate that occur in Calcutta and those of Siler, Hall & Hichens on the apparent frailty of the species, obviously point to some weak link in its life chain. There are large discrepancies in the climatic toleration findings of Gill, Korke & Bruce Mayne. In fact, as Korke (1930b) states, " accurate information on the bionomics and breeding conditions of *fatigans* is wanting."

As stated in the introductory paragraph to this section, and shown graphically in fig. 1, two-thirds of the total adult catch of this species in our area is made in the four months January to April, covering (as Tables VII and VIII show) all the climatic extremes of the period when Rao & Iyengar state that mortality (in cages) is highest. This appears to preclude climatic conditions as causative, for January is usually the coldest and April the hottest month of the year, whilst saturation deficiency is near its minimum in January and around its maximum in April. The only thing that the four months have in common, and in which they differ from the rest of the year, is that they are the months of low rainfall. This is clearly brought out if saturation deficiency (which is a measure of temperature *cum* humidity) and rainfall are plotted in a hythergraph, as described in Shelford (1929). The result is shown for two years only (to avoid overcrowding the figure) in fig. 2. All the months of high *fatigans* prevalence fall to the left of the 3 inch rainfall ordinate, all the other months, when

Fig. 1. *Culex fatigans*, monthly percentage of annual catch.TABLE VIII.
Monthly percentage of *Culex fatigans* caught, Rainfall and Saturation Deficiency.

	1931-32			1932-33			1933-34		
	%	R.F.	S.D.	%	R.F.	S.D.	%	R.F.	S.D.
March ...	21.4	1.3	4.6	28.3	0.7	5.2	23.3	0.0	4.5
April ...	11.5	1.1	5.5	12.0	1.1	6.4	17.2	3.0	5.3
May ...	4.4	7.0	6.0	5.1	11.7	5.5	8.8	7.7	5.2
June ...	4.4	5.8	4.2	2.2	7.4	3.9	3.5	15.8	4.1
July ...	2.2	13.7	3.2	2.0	9.9	2.7	1.5	17.2	2.9
August ...	4.8	8.7	2.5	2.7	9.0	2.7	1.5	14.6	2.8
Sept. ...	2.3	12.7	2.4	2.1	9.5	2.6	3.0	10.5	3.1
October ...	3.0	6.3	2.7	4.0	3.8	3.0	3.8	9.6	3.1
Nov. ...	5.3	5.2	1.6	3.5	9.0	2.3	4.8	0.0	3.7
Dec. ...	6.3	0.0	2.0	8.4	0.0	1.7	9.8	0.0	1.9
Jan. ...	15.9	0.0	1.2	12.1	0.8	2.3	11.2	0.0	2.5
Feb. ...	18.5	0.2	2.4	17.6	2.6	1.9	11.6	0.1	2.4
	100.0	62.0		100.0	65.5		100.0	78.5	

the species is scarce, beyond it. In the Federated Malay States, Gater (1933) shows maxima associated with 2 inches and 4.5 inches monthly precipitation in July and December-January, but his April peak occurs in a month with 10 inches of rainfall. Saturation deficiency apparently plays no part in the pre-adult life of *fatigans*, at least within the limits of variation of this factor in Calcutta.

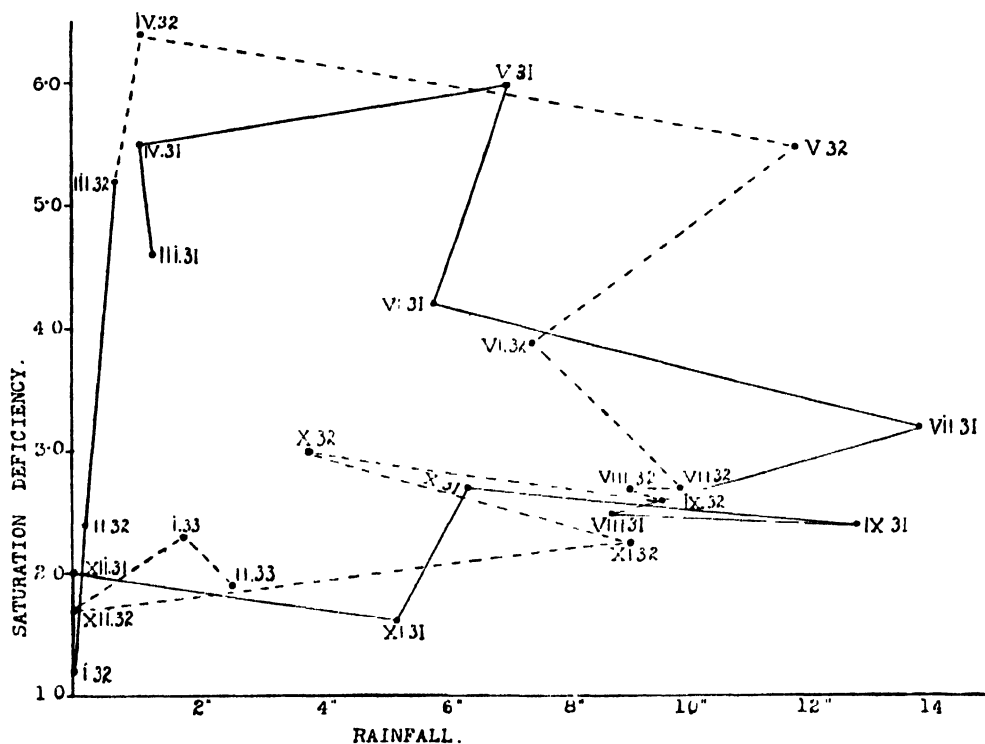


Fig. 2. Hythergraph, Calcutta, 1931-33.

Korke's (1930 a, b) findings are in any case well beyond any deficiency point reached in the City, even if his 50 mm. observation is accepted only with reserve, and remembering Buxton's (1933) dictum that "it is essential to realize that great differences exist between the climate in these spots and that which is generally studied and recorded by the meteorologists." Thus the prevalence of *fatigans* in the City of Calcutta can, I think, be taken to be governed by lack of rainfall. In other words, its major breeding-places must be those that are liable to flushing by precipitation run-off. In Calcutta these will be mainly gully-traps on roadside drain outfalls, and the system of open earth drains, mainly in the suburbs, that lead the sullage (and sewage) of the City eastward towards the rapidly failing system of natural drainage through the Salt Lakes and the Bidyadhari River to the sea. These open sewers, for they are really nothing else, stagnant or all but so, frequently covered with a dense growth of *Eichhornia crassipes* (water hyacinth) are, in the absence of heavy downpours that flush them clear by run-off, simply enormous elongate breeding-places, where larvae can be spooned up at an almost unbelievable density. An observation made in Howrah Municipality (on the right bank of the Hooghly opposite Calcutta) in mid-March 1933, on the actual density of breeding in an open drain produced 35,243 larvae and pupae in 12 dips of a ladle! This is equivalent to a *fatigans* population of 17 to the cc. of surface water, and whilst perhaps more than normally heavy, indicates

the enormous output of *fatigans* from sullage water. Paiva's (1912) figures, however, (his Tables III-V) indicate that quite heavy breeding can go on in drains even through the rains. Fortunately his figures can be used throughout the year, as it is known that the *vishnui*-group is at a minimum during the period November-February when he tabulated it along with *fatigans*.

Period	Percentage of <i>fatigans</i> to all spp.	Percentage of <i>fatigans</i> found in open drains
March-May	55.3	69.2
June-October	47.1	40.7
November-February	59.8	79.1

Gulley-traps in proper drains are, however, flushed clear, and the species carries on mainly in the cesspools and in septic tanks. Many septic tanks in my area have in the past given me considerable trouble to put right, and according to Hamlyn-Harris (1930) 50 per cent. of such tanks produced mosquitos in the City of Brisbane, while he states that if a new tank is sealed with larvae in possession scum does not form, and breeding continues via the gas vent. Failing all else, in septic tanks whose owners will not put them right mechanically, I pour heavy doses of oil* on the sludge chambers, and have not yet had any complaints of interference with bacterial action in consequence.

Consequent on the very intensive anti-mosquito work indicated in the first part of this paper, the area under the control of the Garden Reach Anti-Malaria Association may be taken to be as entirely free from breeding as is humanly attainable; yet, as Tables I-III show, it is still very far from being completely free of adult mosquitos. Save for the winter months, the mosquito density seldom or never amounts to "nuisance" level over the area as a whole, yet there is one catching-station, at No. 11 Garden Reach, located near the house of the Agent (General Manager) of the Bengal-Nagpur Railway, that shows persistently high catches, far surpassing those of any other station. Fig. 3 compares the *fatigans* catch in this station with the average catch in the remaining 10 stations combined, for the year 1931-32, and brings out not only how very much more numerous is *fatigans* in this station throughout the season of its prevalence, but also that practically throughout the year, and very noticeably from December to February, the males exceed the females, whereas elsewhere throughout the area females exceed males.

Average catch per week 1931-32.

	♂	♀	Total	♂%
No. 11	12.0	8.9	20.8	57.4
Average of 10 stations	3.4	5.5	8.9	37.8

The total figures for the above year were submitted to statistical analysis, with the following results:—

Combined stations ♂ : ♀ $r=0.8109$ (a)

No. 11 station ♂ : ♀ $r=0.7589$ (b)

Combined stations total catch : No. 11 total catch $r=0.6344$ (c).

Combined station ♂ catch : No. 11 ♂ catch $r=0.5046$ (d)

Combined stations ♀ catch : No. 11 ♀ catch $r=0.7755$ (e)

*Oil thus used must not, of course, have the 2 per cent. cresylic acid solution added, which here is mixed with oil for spraying to increase spreading power.

These results indicate that there is a special factor at work influencing the composition of the *C. fatigans* population captured in No. 11 station. While the sex proportion there (*b*) is nearly as constant as throughout the rest of the area (*a*), yet comparing the male catches it is seen (*d*) that the co-efficient of correlation between the rest of the area and No. 11 is low. The male percentage discrepancy shown in the table is real, and there are always more males in No. 11 than there normally ought to be. Yet (*e*) shows that a rise in females at No. 11 is closely reflected throughout the area. The inference appears to be that importation into the area occurs at some point not far distant from No. 11 station, and that males accumulate there, whilst females spread themselves generally over the area, though naturally more are found at No. 11 (being the nearest station to the point of importation) than elsewhere.

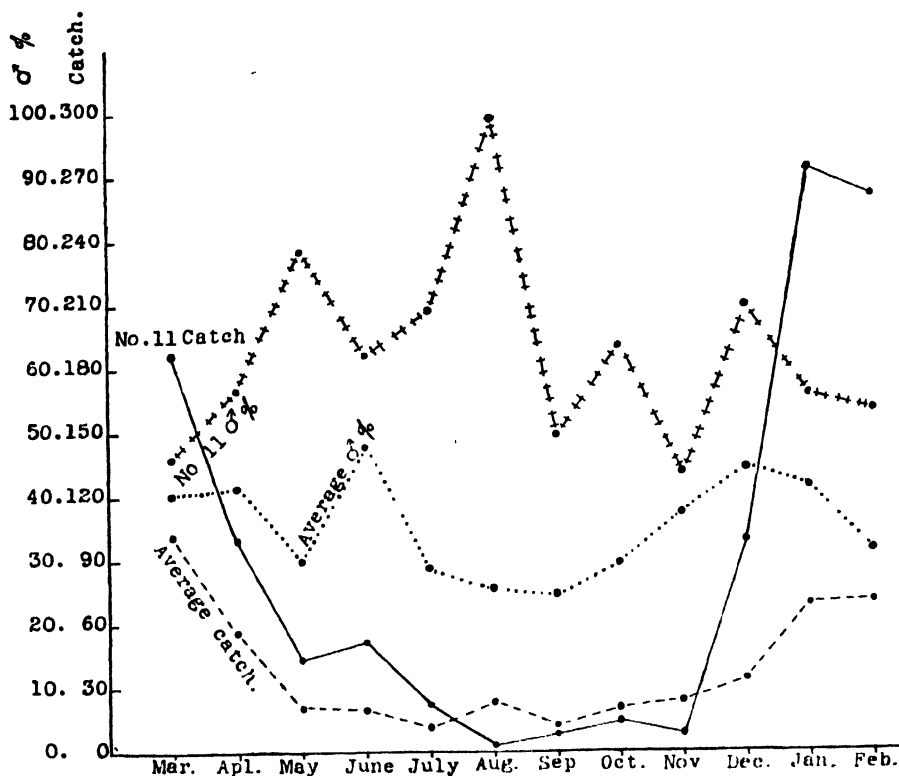


Fig. 3. Prevalence of *Culex fatigans* in No. 11 station as compared with the average for the rest of the area.

Two factors are possible as accounting for this increase in males :—(i) that the source of extraneous breeding is very close, and that the flight of the males is short ; (ii) that there is some characteristic in the build or situation of No. 11 station rendering it specially attractive as a resting place for males. Taking the second possibility first, Pittaluga (1932) has definitely shown that such characteristics exist, though he and his collaborators did not make much progress in elucidating them. Their final conclusions (for *A. maculipennis*) are " la quantité de mâles dans un abri n'est pas toujours en raison inverse de la distance des gîtes à larves, et que d'autres facteurs interviennent dans le choix de l'abri de la part des mâles."

No. 11 station is a watchman's room at the end of a building used as a printing office. The building is screened from the Agent's house by a shrubbery, and there

is much tree shade. It can in every topographical respect be compared with a catching-station, No. 15 Garden Reach, some 1,550 feet to the south-west. This is an entrance gate watchman's shelter hut at the commencement of an avenue of trees, with shrubberies on three sides of it. Yet here the male percentage was only 39.0, which is practically that found for all the ten catching stations other than No. 11. It would appear, therefore, that the second possibility does not apply in the case of No. 11 station, unless there is involved some very obscure factor only discoverable by exact analysis; for shade, humidity and light incidence appear equal for both spots.

Whilst the experimental control of the Shalimar shore, described below, solved the question as to whence came the excess of males, it did not solve the problem of the excess of females in No. 11 catching-station. Dry and wet bulb thermographs were therefore installed in No. 11 and No. 15 catching-stations for some weeks in February and March 1934. The wet bulb instrument in No. 11 was found at the close of the experiment to be defective, and its record cannot be used. As the wet bulb temperature is of far more importance in the life of an insect than the dry bulb, this is exceedingly unfortunate. A figure has been worked out on the assumption that the wet bulb temperatures in each station are equal, and the two relative humidities calculated from the accurately known differences of the dry bulb readings. The figures therefore must be received with considerable reserve.

Now assuming that it is a varying meteorological factor which governs the choice of day-time resting place in a nocturnal insect such as a mosquito, will the critical value governing choice of resting place be that ruling when the insect's activities are stopped by the approach of daylight, or by the most adverse reading achieved in the resting place during the day, which, if it passed a certain point, might reduce numbers by killing them during the resting period? Both are possible, but in climate such as Calcutta in February-March, between extremes of heat and cold and of humidity, I think the latter can be neglected. Proceeding on the assumption that it is humidity at dawn that governs the choice of a resting place, we find that No. 11 catching-station is over 24 days in February at 6 a.m., on an average 12 per cent. more humid than No. 15, and over 18 days in March 6 per cent. more humid. These are small differences considering the errors involved in the method of evaluation, and cannot be said to do more than suggest more careful experiments, with daily catches, in the future. There is no direct relationship so far revealed between excess percentage of humidity, and excess numbers in female catches.

Turning now to the first possibility, while it is absolutely certain that breeding is not topographically very close to No. 11, yet a very peculiar condition exists that in practice actually makes it so. This is the existence of a railway waggon ferry from a point close to No. 11 to the railway yards on the right bank of the Hooghly at Shalimar. The journey performed by the ferry steamers is not a direct crossing of the river, but involves going up-stream some seven-eighths of a mile in addition. The river is about three-eighths of a mile wide opposite Garden Reach widening to about half a mile opposite the landing pontoons at Shalimar. The waggons are hauled individually on and off the ferry steamers by power-operated cables, a slow process, involving a halt of about an hour at each side. Traffic usually continues, several ships being employed, for about 18 hours a day.

Shalimar railway-yard is in Howrah Municipality, the general sanitary condition of which is deplorable, and which makes absolutely no attempt to control mosquitos. The Municipality's swampy night-soil trenching-ground north of the Railway Area renders nearly all the water in the vicinity, in borrow-pits and tanks, suitably polluted for *fatigans* breeding, in addition to surface drains in a state at least no better than those on the Calcutta side were in originally. Breeding is of the utmost intensity. Attempts to form an Association similar to that at Garden Reach have found no support among the industrial firms operating in the Shalimar area, and though in the

winter of 1932-33 the Railway attempted to control breeding in its own area, especially in the neighbourhood of the ferry pontoons, it was not practicable to make much impression on its intensity, just as was originally found at Garden Reach. The results of intensive control by the railway in the season of 1933-34 are referred to on p. 579.

A casual inspection of the ferry steamers revealed that they were full of mosquitos. A ten minutes only catch in the forecastle of one in February 1931 produced :—

<i>Culex fatigans</i> ...	...	...	...	3 ♂	102 ♀
<i>Stegomyia fasciata</i> ...	...	...	...	1 ♂	8 ♀

This might have been the result of breeding on board the ships, but from September 1931 control of these was instituted, and though the *Stegomyia* population thereafter dropped almost to zero, yet each winter *fatigans* has been extremely numerous on board.

It was next necessary to prove that such mosquitos actually embarked at Shalimar and disembarked at Garden Reach. An initial observation gave the following results (February 1931) :—

The Chief Engineer's cabin on a ferry steamer was emptied of all mosquitos whilst the vessel was at Garden Reach. This took 45 minutes, and resulted in a catch of about 75. The cabin was then empty save for a very few thoroughly disturbed specimens that refused to settle. As the ship approached the landing stage at Shalimar, though the cabin was on the stream side of the vessel, *C. fatigans* invaded it before the ship was even made fast. The ship remained at Shalimar for 64 minutes, and after getting under way the cabin was again emptied of mosquitos, resulting in a catch of *C. fatigans* 9 ♂, 44 ♀; *S. fasciata* 1 ♂. All these mosquitos had apparently come on board during the halt on the right bank of the river.

It was then necessary to prove that such mosquitos actually disembarked at Garden Reach. Visual observation indicated that they did so, as it was seen that mosquitos resting in sheltered spots during the passage (which in winter involves a head-wind on the trip to Garden Reach, excluding that created by the ship's own movement) took wing and disappeared as soon as the bump against the landing pontoon on arrival jarred the ship. Accordingly in March 1933 a series of catches were made in ships during the voyage and after arrival, catching out two officers' cabins of similar size adjacent to one another, as far as possible completely, and not for a limited period, as in routine sampling. To avoid any possible difference in attraction effect between the two cabins, these were alternated every time for "voyage" and "arrival" catches. Eighteen voyages yielded the following totals.*

TABLE IX

	Total		Average per voyage	
	♂	♀	♂	♀
Caught on voyage ...	33	204	1.8	11.5
Caught after arrival ...	12	57	0.7	3.2
Reduction per cent. ...	64	72		

Males and females therefore both utilise the ferry steamers for crossing the river, and both disembark in approximately the same proportion of two-thirds of their number, immediately they touch land again.

*Compared with the figures mentioned previously for 1931, it does appear that the Railway-operated control on their area at Shalimar was having some effect on the density of mosquitos on board.

It is not of course suggested that this performance is volitional. During the halt at Shalimar the steamer becomes virtually a part of the mosquito-infested right bank of the river. This part is then mechanically transported to the left bank, with its initial mosquito population. The same phenomenon was reported as occurring at Khartoum by Balfour (1920).

However, there is only one way of settling the question absolutely, and that is by means of marking experiments. These have not been extensively carried out, even with Anophelines, and no work whatever appears to have been done on any Culicine.*

In my experiment freshly emerged bred adults were used. The exact number of each sex used is not known, as it was impossible to count the closely huddled mosquitos in the breeding-cage. The total released is known from the number of pupae placed in the breeding dish in the cage, and the number of these that were found to have failed to emerge after the cage was opened. The stain used was 2 per cent. watery eosin applied with an atomizer spray. 662 adults were released in an empty cattle-shed about 100 yards from the river bank at Shalimar at 8 p.m. on 16th March 1933. There is quite a considerable human blood supply in the vicinity of this shed without the mosquitos having enforced recourse to the crew of the ferry steamers for blood, and I think it must be accepted that in all probability the released swarm radiated through every degree of the compass, and that there could be no particular urge to concentrate on the ferries.

The subsequent history of this experiment was :—

16th March.—One unfed ♀ recaptured on a ferry during voyage at 10 p.m. (2 hours after release).

17th March.—(a) One unfed ♀ at 8.30 a.m., in my Laboratory Assistant's quarters, which were approximately 1,050 feet from the Garden Reach shore ferry pontoons, and were at this time being caught out completely morning and evening in connection with experiments to be described later ; (b) one unfed ♀ on a ferry steamer at Garden Reach at 6.50 p.m., which must have left its previous night's resting place and boarded the steamer with the first movements of mosquitos at dusk ; (c) one ♂ on a ferry during voyage at 8.30 p.m.

18th March.—(a) One unfed ♀ at 6.30 a.m. in No. 11 catching-station, which is some 550 feet from the ferry steamer pontoon ; (b) one ♂ in my Laboratory Assistant's quarters at 8.30 a.m.

19th March.—One ♂ in my Laboratory Assistant's quarters at 8 a.m. Thus seven specimens in all were recaptured, which is 1.06 per cent. of those released and (assuming that in the hatch males and females were present equally) 0.9 per cent. of the males and 1.21 per cent. of the females released.

Now in making the catches in which these seven specimens were re-taken, 175 males and 180 unfed females were examined. The re-captures represent 1.71 per cent. and 2.22 per cent. respectively of the numbers examined. When one considers how minute a proportion of the total mosquito population of an inhabited area is represented by the population of the six† stations from which the catch was tested for stain, the recovery of four mosquitos (*i.e.*, excluding those caught on the ferry steamers) would appear to show that these steamers are responsible for the excessive catches at No. 11 station, which is the one nearest the ferry pontoons.‡ The excess of males here is not explained by this, for the capture of two in my Laboratory

*Kligler (1925) gives a list of stained flight records up to the date of his paper. Since then I can only trace four more papers on the subject : Davis (1926), Kumm (1929), Hackett & Missiroli (1931a), and Hackett, Martini & Missiroli (1932).

†My Laboratory Assistant's quarters were being caught out completely twice daily at this period, so eleven catches in all were made.

‡But see page 575, describing evidence to the contrary.

Assistant's quarters, twice as distant from the pontoon, does not suggest either short flight distance or any particular attractiveness to males inherent in No. 11 station.*

It is by no means certain that males do not also actually make the cross-river flight without the aid of the ferries. Table IX shows that males are much less numerous on board than females, and it will be noticed that while two out of four stained females re-captured were taken on ferries, only one out of three males was so re-taken.*

Against this, however, is the fact that catches in the Hooghly Mill station, at that time in a room on the river bank about 850 feet east of No. 11, were uniformly very low, and without any unusual preponderance of males.

Even when there is no apparent increase of *fatigans* nuisance at Garden Reach, swarms of males dancing overhead at dusk are frequently seen in that part of the area close to the river bank.

As a matter of fact a second staining experiment indicates that males have a longer flight range than females. On 25th March 1933 at 5.30 p.m. 1,588 bred adults were released at a point beyond the controlled area southwards of it. On the morning of 26th March 1 male was recovered at a point 1,210 yards distant. On 27th morning 2 single males were taken at points 1,540 yards and 2,310 yards distant. No females were recovered. During the 48 hours of these flights the wind had averaged 3 m.p.h. only, and varied from dead calm to a S.S.W. direction.

The data thus obtained on ferry steamer importation of *C. fatigans* into the control area were put to practical test in the winter of 1933-34. The Railway doubled its subscription to the Garden Reach Association, with back effect from the commencement of the financial year in April, rendering sufficient funds available to place a half-mile area centred on the ferry pontoons at Shalimar under full control, irrespective of ownership of the area involved, from December to March. The results were very striking. The male percentage at No. 11 catching-station, which in November had been virtually the same in both years, immediately dropped to a figure in conformity with the rest of the check stations, as Table X shows.

TABLE X.
Culex fatigans male percentage.

				No. 11 catching-station		Rest of area
				1931-32	1933-34	1933-34
November	...	...		44	40	18
December	...	...		70	21	21
January	...	...		56	7	19
February	...	...		54	15	20
March	...	...	...	49	23	20

Now Table IX shows that at no time are there very many males on the ferry steamers. It is thus fairly certain that the majority of males cross the river by direct flight, a distance which the staining experiment described on p 578 suggest they are capable of accomplishing. There was no corresponding reduction in females at No. 11, and though the benefit to the residents of Shalimar and the crews of the ferry steamers was immense, there was no appreciable decrease of females at Garden Reach. This,

*But see page 575, describing evidence to the contrary.

in the light of the ferry steamer findings, was entirely unexpected, but the knowledge that female invasion from the right bank of the Hooghly had been enormously reduced* enabled further investigations to be undertaken into the source of the still far from negligible *fatigans* nuisance of February–March. This nuisance, as shown on p. 572, in part arises owing to this being the period when saturation deficiency values render the mosquitos most voracious, but there is a real steady influx of *C. fatigans* females at this time of year into Garden Reach. In 1934 it was on the night of 7th February that the nuisance first became apparent in my own flat, though occupants of other flats in the same block had complained four days earlier.

That this was primarily a voracity phenomenon is abundantly clear from the meteorological record. The 1st to 6th February was a period of quite unusually high saturation deficiency for the time of year, averaging 4 mm. as against 2.2 mm. for the same period of the previous three years. I decided to evaluate the actual mosquito invasion by having my flat (6 rooms) caught out completely on every morning on which there was staff available to do so. The results were as under :—

Month	Catching days	Catch		Per catch ♀	Abdominal stages							Maximum ♀ on any one day
		♂	♀		I	II	III	IV	V	VI	VII	
February ...	11	4	28	2.5	0	20	2	1	1	2	2	6
March (to 22nd)	20	28	123	6.1	19	58	11	4	6	8	17	14

From 24th March onwards the catch dropped to zero, and observations were discontinued.

A further fact emerges, that it was my own bedroom, facing east, in which nearly all the fresh engorged (stage II) females were taken, the later stages being generally distributed throughout the house. The occupant of the bedroom facing west only complained of nuisance during the actual maxima in early March. Now the nuisance more or less coincided with the general change in the direction of the 10–11 p.m. wind from almost due west to south-west, as detailed in Table III of Appendix A of Covell (1932).

At the end of February we discovered that the Calcutta Corporation Mosquito Control Department had temporarily run out of larvicides during January, and that in consequence there was very heavy breeding going on in the east and south of the Association's perimeter. As complaints from residents in that sector were general, it was decided to oil beyond our boundary as an experimental measure, from the reserve fund accumulated for contingencies of this nature. This was done from 7th March to the end of the month. No improvement whatever was visible, either at No. 11 station, or at the Kidderpore Docks and Dumayne Avenue stations, the two stations towards the eastern boundary of the controlled area, and both less than half a mile from it,† where one would expect any benefit to be most apparent. This suggests that the flight distance of female *fatigans* is comparatively short, however heavy the adult production may be, at least in the presence of a dense population close to the breeding-grounds.

*Ferry steamer catches in March 1934, compared with March 1933, showed an average "per cabin per trip" reduction of *C. fatigans* from 2.5 ♂, 22.2 ♀, to 0.6 ♂, 5.7 ♀, being 72 per cent. for males and 68 per cent. for females. These figures differ from those in Table IX, owing to the fact that the 1933 figures used are not in every case the results of the same trips as figures in the table. They are "arrival," not "voyage" catches.

†On the eastern boundary of the control lies an exceedingly "tough" district full of Lascar seamen's lodging-houses, etc., which it is quite impossible for a private Association to attempt to deal with. When doing work in March 1934 the police detailed special protection to our men when working in the backyards and lanes of this area.

As regards Garden Reach itself, then, all that comes out of the extended controlled areas of 1934 is to show that the male *fatigans* population there is the result of the long flight power of this sex, and can be reduced only by such extensions of work, which, except in so far as they benefit their immediate vicinity by female reduction, are of no practical value, and do not reduce the female-caused nuisance in the Garden Reach area at all. Considering the big reduction in the female ferry importation as shown in the figures in the footnote on p 580, this result is at present incomprehensible.

Another point which catches on the ferry steamers have brought out is that *C. fatigans* appears to be most motile in the first two hours of darkness, as the following table shows :—

TABLE XI

Time	A. Early March 1933 Heavy breeding		B. End of March 1933 Breeding slackening	
	No. of catches	Average per catch	No. of catches	Average per catch
Dusk-7 p.m. ...	2	34.5	0	—
7 p.m.-8 p.m. ...	6	35.8	3	4.0
8 p.m.-9 p.m. ...	7	25.9	4	3.7
9 p.m. 10 p.m. ...	6	14.3	0	—
After 10 p.m. ...	5	9.2	7	2.1

Now it can be taken that the controlled square mile at Garden Reach is in the nature of a mosquito vacuum, into which adults enter to feed. Whether they also enter to oviposit will depend on whether, at a distance, they can distinguish oiled water from unoiled, also on the quite unknown flight powers of the egg-laden female. Whatever be the case, the Chief Inspector of the control informs me that it is now most unusual to find, on the weekly oiling day, that any particular breeding-place has had egg-rafts deposited since the previous week's oiling except near the boundaries of the control. It would appear therefore that only hungry adults penetrate, and further, if this inference is correct, the central areas of the control must be in the nature of a trap; for though the empty mosquito may fly long distances to feed, the heavily egg-laden insect that ensues probably cannot cover the same distances in returning in search of non-oiled water available for oviposition. It seemed, therefore, that studies in the composition of the *C. fatigans* population of the area would yield interesting information, in the same way as this has done in connection with the study of Anopheline movements by several workers, notably Kligler (1932, 1933) in Palestine.

The method adopted was that of Grassi & Sella (1920) as modified into seven stages by Boyd (1930a). The appearances in *Culex* closely approach those illustrated in his figure 60 for Anophelines, but there are one or two differences needing mention. Firstly, coagulation is so rapid in *fatigans* that a mosquito captured in the morning after feeding seldom shows the ingested blood red but nearly always black.* Secondly, partial feeds appear comparatively frequent in *fatigans*, the anterior portion of the abdomen being seen to be full of gas. The position of the distal end of the blood mass has in such cases been taken as the classificatory point, neglecting the condition of the anterior end of the abdomen. Thirdly, in stage VI, the residual trace of blood is not invariably at the anterior end of the stomach, but is at times seen as a

*I noticed that at Ranchi (2,062 ft.) this is not the case.

black streak on the ventral edge of segments 3 and 4.* Finally, in the third year's work, stage I was separated into (a) virgin females and (b) multiparae, so far as this can be done by external inspection, the criteria being whether the pleura is clearly visible between tergite and sternite, as is the case after one pregnancy, or not.

There is almost certainly some percentage of error involved by so crude a method, and it probably operates both ways, a few virgin females that have imbibed a nectar meal being placed as multiparae, and probably greater number of multiparae whose pleurae have contracted being classified as virgins; but in spite of this drawback, the method has yielded certain interesting results. These are included in Table XVII, from which fig. 4 is constructed.

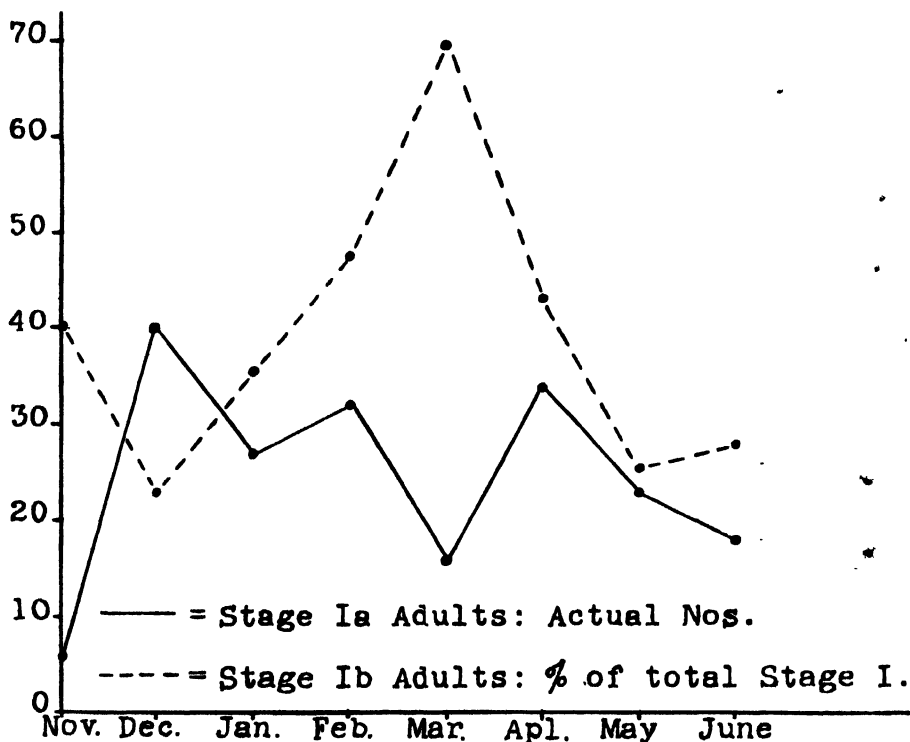


Fig. 4. *C. fatigans*, analysis of unfed captures.

From the figure, which refers only to the months November to June, when there are fair numbers of stage I in the catches, it will be seen that March, the month in which the total catches of all stages is the highest, has a very low stage Ia catch. On the other hand, there is in this month alone, a reversal of the proportions of stage Ia to Ib, the latter, as in no other month, considerably exceeding the former. The first of these results was quite unexpected. In a month of maximum prevalence, one would look for a corresponding maximum of newly eclosed specimens. The explanation that at once suggests itself for the discrepancy is that, this being the month when meteorological conditions favour the highest voracity, newly emerged adults feed immediately, reducing their apparent morning numbers, but the findings given below negative this idea. How comes it then that adults are most numerous in March, if

*According to Boyd (1930b) these would be females with mature eggs that have taken another feed before oviposition. This would be, I think, an unusual happening. The author omits the stage from his text-book (Boyd 1930a), and I have placed such specimens in stage VI. The trace of blood appears invariably (in *fatigans*) residual and not freshly imbibed.

there really is a low production? Does the high percentage of stage Ib account for it, in other words, is each generation much longer-lived than at other periods, so that a large part of the March population is that surviving from February? Until the relative output of a breeding-place has been measured month by month, which involves studies that cannot be made in a controlled area, this hypothesis cannot be tested. Apparently against it is the fact that, as fig. 7 shows, the percentage of stage Ib in any month is very constant; but while the ratio is steady, the actuals are seen from Table XVII to be increased *pari passu* with the general increase of the species. In any case, within a controlled area, the numbers of stage I are low, compared with normal conditions, as fig. 5 shows. Further progress in our knowledge of the bionomics of this insect will have to be achieved by studies carried out in an area where no artificial interference with the species is occurring.

Another point which it would be useful to know is the time intervals represented by these stages. Owing to the extremely heavy cage mortality in this species, which has been my own experience equally with that of other workers, this has not been at all simple to discover. Freshly emerged females will not feed full in captivity, presumably because fertilisation rarely occurs, and in spite of large batches being used, by the time stage VII has been attained, the remaining females have failed to oviposit, and as will be seen later, there is indirect evidence that the attainment of stage VII and readiness to oviposit are not the same thing. The average of experiments, conducted between 24th February and 17th March 1933, gave as follows, there being no indication that the stages proceeded more rapidly in the last than in the earlier experiments, in spite of the rising mean temperature. Adults captured full-fed in mosquito-nets were used, and since the actual hour of feeding (*i.e.*, the start of stage II) was not known, this was assumed to be midnight.

TABLE XII.

Stage I-II	...	...	...	...	?
Stage II-III	...	...	...	...	34.25
Stage III-IV	...	...	...	...	7.25
Stage IV-V	...	...	...	...	?
Stage V-VI	...	...	...	...	?
Stage VI-VII	...	...	...	...	?
Stage IV-VII	...	...	...	...	16.75
					<hr/> 58.25 hours <hr/>

The time from emergence to feeding can be approximately estimated from the staining experiments described on p. 578. The female recaptured, still in stage I, on the morning of 18th March was then between 40 and 64 hours from the pupa. As it would not feed until the 18th evening, the length of stage I appears to be from 50 to 74 hours. This gives a minimum of $4\frac{1}{2}$ days from emergence to oviposition, which is much shorter than the minimum time for pre-adult development given by Pomeroy (1920). Under favourable conditions, therefore, generations will overlap continuously; thus, starting from the commencement of favourable conditions locally with the start of the dry weather in December, March, the month before suitable waters commence to dry up, would be expected to show the maximum adult population. Add to this that Bruce Mayne's (1930) results show that the biting reflex is at its highest under meteorological conditions corresponding with those of Calcutta in March, and it becomes clear why that month shows the maximum mosquito nuisance of the year. The work now to be described was carried out in February and March, the months of maximum prevalence, which as will be shown later,

do not differ so markedly from other months that the results cannot be taken as generally applicable to the life-history throughout the year.

In order to have a basis for study of findings in the controlled area it was necessary to know what are conditions in an uncontrolled area. For this purpose a Laboratory Attendant who lived at that time in an uncontrolled area in the City, the suburb of Ballyganj, was instructed to make daily morning catches in his own house and those of his neighbours. The results (also shown graphically in fig. 5) are as follows :—

TABLE XIII.

Total catch	Percentage in stage						
	I	II	III	IV	V	VI	VII
744	42	12	8	7	6	5	20

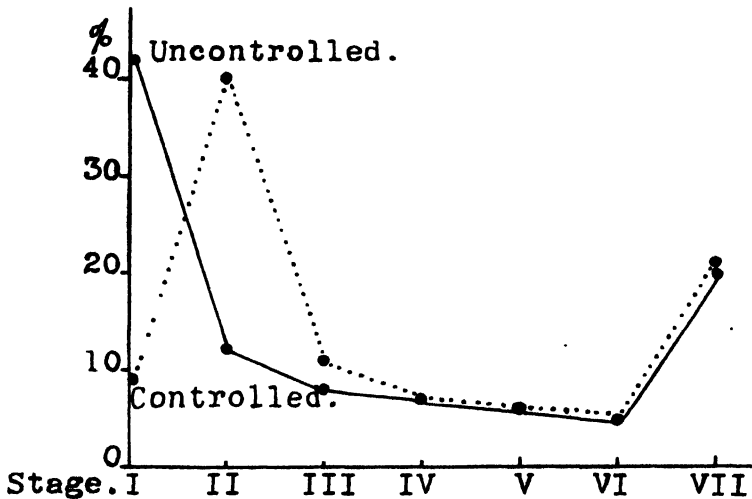


Fig. 5. *C. fatigans*, percentage of stages in controlled and uncontrolled areas.

From stage I to stage VI this gives an absolutely smooth curve of extreme interest.* The extremely high percentage of unfed specimens *captured in the morning* must represent a resting collection of the previous night's eclosion that are not yet ready to feed. The steady fall up to stage VI is very interesting. In a large city there can be no question of failure to feed, and so to pass to stage II, through lack of blood supply. The fact that there are $3\frac{1}{2}$ times as many stage I as stage II present suggests that the higher figure (74 hours) for stage I deduced from the marking experiments is more correct than the lower. It would also appear that only about an eighth of the female mosquito population of a house in normal circumstances is in a state to bite. The steady reduction in the subsequent stages up to VI can, I think, only indicate the natural death-rate that occurs, and reflects all that has been found by other workers regarding the frailty of this species, or else is a measure of the toll taken by predators (spiders and lizards in houses, bats whilst flying), for, as the next experiment shows, this species is on the move in all stages. As Hackett & Missiroli say regarding *A. maculipennis*, "In the course of the routine work of the Malaria Experiment Station in Italy, we have often been struck by the fact that the capture at any time of all the

*By re-plotting the curve with the reciprocals of the figures for each stage as ordinates, this curve appears to be the exponential catenary curve of Janisch (Uvarov, 1931).

Anophelines in a given stable will not affect the diversity of abdominal contents of the Anophelines found in the same place the next day. The new-comers entering each night are not even predominantly empty females looking for blood ; mosquitos in every stage of blood digestion are on the move, including those with eggs almost at maturity." In an experiment they found (their classification of stages being adapted to that used in this paper) :—

Stage					Percentage leaving	Percentage staying
I	...	...	...	...	23	2
II	...	...	...	...	28	62
III }	...	...	...	...	15	18
IV }	...	...	...	...
V }	...	...	...	...	11	12
VI }	...	...	...	...
VII	...	...	...	...	23	5

But what is the cause of the big rise in the percentage in *C. fatigans* in stage VII ? I think it can only mean that there is a considerable period when the eggs though apparently mature are actually not ready for deposition. I have found elongate and apparently mature eggs in stage VI, whilst on the contrary I have found globular, obviously immature eggs in stage VII. As the time intervals represented by the various stages are not known, this period cannot be stated in terms of hours, but it is

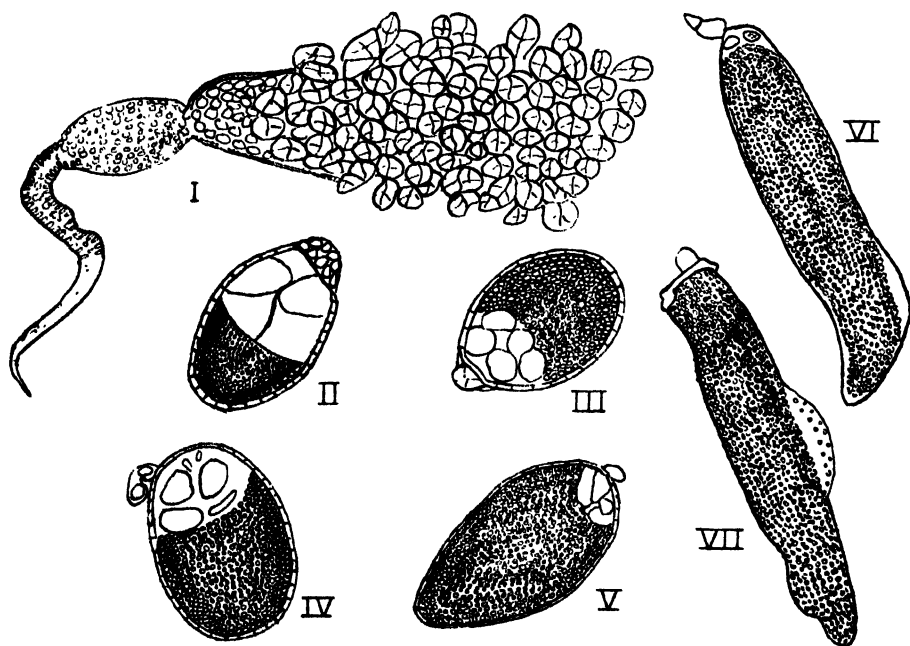


Fig. 6. *C. fatigans*, development of the egg : I, ovary in stage 1a ; II-VII, egg-follicle in stages II-VII respectively.

four times as long as the preceding stages of digestion and ovarian maturation. It will be seen to be a universal phenomenon in the life-history of *fatigans*.

The condition of individual egg-follicles from females in abdominal stages I-VII, as normally seen, is illustrated in fig. 6. The work of Nath (1924) shows a peculiar chitinous collar round the micropylar apparatus in *C. fatigans*, which he states is developed only a short time before fertilisation, which takes place when the egg is passing down the common oviduct. This feature should enable one to subdivide stage VII into eggs that are actually and those that are only apparently mature, and so elucidate what is happening during the "pile up" of stage VII females in a resting place. But I have been unable to distinguish this collar myself in any of the specimens I have dissected. The remains of the nurse cells are certainly present, as fig. 6, iv, shows, but by ordinary microscopical methods suitable to the routine examination of large numbers of specimens, the point where these residual structures develop into the actual collar is not apparent, and the structure unfortunately cannot be used for subdividing stage VII.

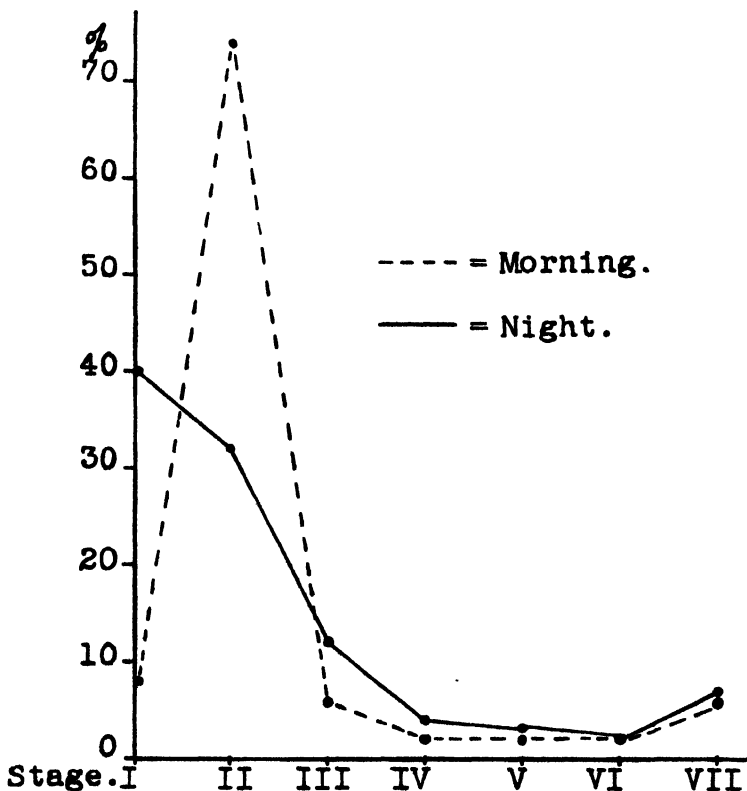


Fig. 7. *C. fatigans*, percentage of stages in night and morning catches (controlled area).

To prove that this species, like *A. maculipennis*, is on the move in all stages, I arranged for my Laboratory Assistant's quarters to be completely caught out morning and evening for a period of three weeks. The quarters are small, and the man is the most skilled catcher on my staff. It can be taken that every mosquito which entered early in the night, or was present in the morning, over this period, has been examined, and that no single mosquito has been in the house longer than 12 hours.

The hour of the evening catch varied from 8 to 10 p.m. The morning catch was always made soon after daylight. The results are as follows and are also shown graphically in fig. 7.

TABLE XIV.

	Percentage in stage						
	I	II	III	IV	V	VI	VII
Evening catch : total 818	40	32	12	4	3	2	7
Morning catch : total 814	8	74	6	2	2	2	6

These evening figures prove conclusively that adults in all stages are on the move. Nearly as many freshly fed adults enter the house as do unfed adults. During the actual digesting stages from III to VI the adults are relatively much more stationary in habit, but with ovaries mature (so far as the present investigation has gone) there is a slightly increased tendency to wander. Finally, the very close agreement of the morning and evening catches, which was not noticed until the results were totalled, proves that, in any house, ingress and egress are equal.

Having settled these preliminary fundamental points it is now possible to examine conditions in the controlled area. The results of the twenty-minute check catches in the eleven regular stations, plus two extra stations similarly utilised, make up the figures, which cover most of February and March 1932. The results, also shown graphically in fig. 5, are :—

TABLE XV.

Total	Percentage in stage						
	I	II	III	IV	V	VI	VII
1190	9	40	11	7	6	5	21

The differences between this curve and that for an uncontrolled area are as striking in respect of stages I and II as are the similarity of the later stages. The reason for the differences in the proportions of early stages is that, as there is no breeding in the controlled area, there is no large population of newly emerged, immature, unfed specimens. The staining results given on p. 578 indicate that even these wander before they are ready to feed, hence the area will be infiltrated by specimens not yet ready to feed as well as by hungry insects, though the latter seem, as would be expected, to invade it much more numerous. Komp, quoted by Mink (1933), states that any mosquito which attacks man "will, if produced in excessive numbers, fly much further than is normally considered the flight range of that particular mosquito." Until the Calcutta Corporation re-initiated serious anti-mosquito work in 1933, and again in February–March 1934, when this ceased through their Mosquito Controlling Officer not being supplied with oil, such conditions obtained round the Garden Reach control area. But in the controlled area there is an enormous reduction between stage II and stage III that escapes explanation. Why should over three-quarters of the insects that feed disappear in the next 36 hours, whereas in a normal, uncontrolled area only 4 per cent. do so.* Difference in population of predators cannot be invoked. In none of the catching-stations, naturally, are insecticidal

*The daily morning catches in the Laboratory Assistant's quarters exhibit this phenomenon in an even more exaggerated form (fig. 5).

sprays in use. The figures from stage III to stage VII are so similar to those for the uncontrolled area that one might almost be observing the working of a "law" governing the percentage of the later stages, which cannot be changed by anti-larval operations. Obviously very much more experimental work is required.

From these sets of figures one very important practical point emerges. *If in a controlled area a high percentage of stage I adults is found in morning catches, then the control work is faulty and breeding is occurring near by. If, on the contrary, the percentage of this stage is low, then all the adults found are invaders, and if (as in anti-malaria work) it is essential to reduce their numbers still further, the bounds of the control must be extended.*

The composition of this invading population was studied by means of night catches at the following points:—(i) a disused cattle-shed at Shalimar; (ii) on ferry steamers during the crossing of the river; (iii) on ferries after arrival; (iv) after penetrating the controlled area by 1,050 feet to my Laboratory Assistant's quarters.

During this journey, the insects have had continually increasing opportunities of feeding. Between (i) and (ii) on the night workers in the railway yard at Shalimar; between (ii) and (iii) on the crew of the steamer; between (iii) and (iv) on the night workers in the railway yard at Garden Reach, and various houses and blocks of servants' quarters between the river bank and point (iv). The results are very instructive.

TABLE XVI.

Catching place	Total	Percentage in stage						
		I	II	III	IV	V	VI	VII
(i) Shalimar	281	84	12	0	0	2	1	0
(ii) Ferry on voyage	179	58	25	6	2	1	2	6
(iii) Ferry on arrival	814	49	17	15	4	6	3	6
(iv) Garden Reach quarter	818	40	32	12	4	3	2	7

From point (i) it was at that time an easy flight distance in three directions to water suitable for oviposition, hence the almost complete absence of the later stages.

Study of the second line in Table XIV shows what had happened to this invading population by the following morning. The matter is made clear if the actual figures from the protocols are used.

		Stage I	Stage II
Caught in quarters at night		323	264
„ „ in morning		62	608

Therefore 261 (81 per cent.) of the invaders of the previous night have fed.

These investigations yielded so much information that abdominal classification of the check catches was carried on for an entire year, from April 1933 to March 1934. The figures of the results, given in Table XVII, include those from the Hooghly Mill station, making 12 stations in all, or 240 minutes catching per week. In preparing fig. 8 from Table XVII the July and August results are neglected, as the totals in these months are so small that the possibility of error is large.

The first point to be noted is that the curves for the year do not differ essentially from that obtained in the February–March controlled area observations graphed in fig. 5. Therefore the results discussed previously can be taken as applicable to the

whole year. Stage I is divided as described on p. 582, and in fig. 8. Stage Ib is placed in its logical position chronologically, after stage VII.

TABLE XVII.
Analysis of Culex fatigans female catch. All Stations 1933-34.

Month	Total									Per cent.							
	Ia	Ib	II	III	IV	V	VI	VII	Total	Ia	Ib	II	III	IV	V	VI	VII
April ...	34	25	183	64	17	20	30	108	481	7.1	5.2	38.0	13.3	3.5	4.2	6.2	22.4
May ...	23	8	156	37	12	13	21	57	327	7.0	2.4	47.7	11.3	3.7	4.0	6.4	17.4
June ...	18	7	54	21	7	8	7	20	142	12.6	4.9	38.0	14.8	4.9	5.6	4.9	14.1
July ...	1	2	21	7	1	7	4	12	55	1.8	3.6	38.2	12.7	1.8	12.7	7.3	21.8
August ...	2	1	15	8	3	3	6	12	50	4.0	2.0	30.0	16.0	6.0	6.0	12.0	24.0
Sept. ...	1	2	53	10	4	5	9	22	106	0.9	1.9	50.0	9.4	3.8	4.6	8.5	20.8
October ...	2	3	63	12	7	12	11	20	130	1.5	2.3	48.5	9.2	5.4	9.2	8.5	15.4
Nov. ...	6	4	67	30	9	15	9	44	184	3.3	2.2	36.4	16.3	4.8	8.2	4.8	23.9
Dec. ...	40	12	103	48	20	24	24	95	366	10.9	3.3	28.1	13.1	5.5	6.6	6.6	26.0
Jan. ...	27	15	102	67	37	26	41	100	415	6.5	3.6	24.6	16.1	8.9	6.3	9.9	24.1
Feb. ...	32	29	148	73	27	35	19	85	448	7.1	6.5	33.3	16.3	5.5	7.8	4.2	19.0
March ...	16	37	289	67	37	24	38	85	593	2.7	6.2	48.7	11.3	6.2	4.0	6.4	14.3
Average 10 months										6.0	3.8	39.3	13.1	5.2	6.0	6.6	19.7

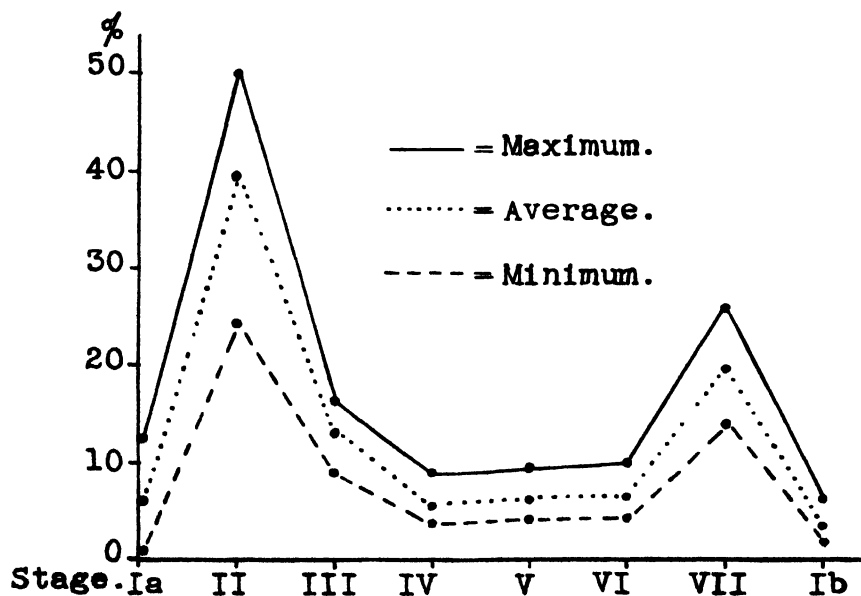


Fig. 8. *C. fatigans*, maximum, minimum and average percentages of abdominal stages for one year (controlled area generally).

It is seen that in any given morning collection of female *fatigans*, stages II and VII, those freshly fed and those with digestion complete and ovaries apparently mature, will predominate. Further, three stages show wide ranges of variation, *viz.*, Ia, II and VII, while the intermediate, digesting, stages, and the proportion of females surviving oviposition and ready to feed again, are very constant. In the absence of any information on the seasonal incidence of predators, a meteorological explanation of these phenomena must be invoked. As fig. 9 shows, there is a rectilinear relation between the percentage of the catch found in stage II and the 8 a.m. wet bulb temperature, between the months of September and March, the months when the species is on the increase; but this relationship entirely breaks down from April to August, the months when the species is on the decline. This decline is the result of drying up of water suitable for breeding, followed by monsoon flushing, but the failure during this period to follow the temperature curve in feeding suggests that, during the two seasons when conditions are most unsuitable for breeding, there is some measure of asthenobiosis in play. In occasional dissecting I have never seen anything suggesting fat-body development or hypertrophy of the Malpighian tubules, but a study of this would form an interesting line for future research.

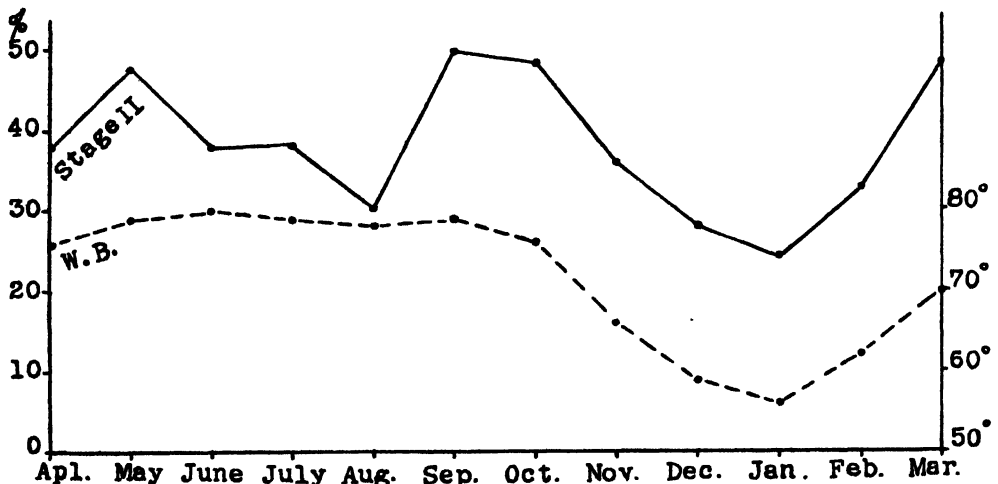


Fig. 9. *C. fatigans*, percentage of females in stage II compared with the 8-00 hours wet bulb temperature.

No meteorological relationships can be found for variations in stage Ia and stage VII. Now these stages are those directly connected with water suitable for the pre-adult stages, Ia because it is just emerging therefrom, VII because it is seeking or about to seek such for oviposition. Fig. 5 shows the enormous difference in respect of stage I that exists between a controlled and an uncontrolled area, but it has not been possible to study the subdivision of the stage under the latter condition. However, it is certain that under the former, stage I as a whole is under abnormal conditions, and it is therefore not worth seeking for meteorological relationships. As regards stage VII, fig. 5 shows that, apparently, control makes no difference to the percentage found in this stage. Unless it has a much longer flight range, than would *prima facie* appear probable, this is hard to believe. In any case, I have failed to find any direct meteorological relationships, and the cause underlying the seasonal fluctuations remains entirely obscure.

Within the range of the various meteorological factors obtaining in Calcutta it is apparent that the stages in which digestion and ovarian maturation occur, and the numbers successfully surviving oviposition, are very constant. It would be extremely

instructive to study the species in a locality where wider ranges of temperature and humidity occur.

The figures accumulated during this particular investigation have also served to elucidate the composition of the female catch in No. 11 station. Regarding this the following points were already known :—(i) From the table on p. 574 it is always much higher than at any other station ; (ii) statistical analysis (p. 575) shows that it

TABLE XVIII.

Analysis of Culex fatigans female catch. No. 11 Station, 1933-34.

Month	Total									Per cent.							
	Ia	Ib	II	III	IV	V	VI	VII	Total	Ia	Ib	II	III	IV	V	VI	VII
April ...	9	12	25	8	6	3	9	36	108	8.3	11.1	23.1	7.4	5.6	2.8	8.3	33.3
May ...	4	1	1	2	2	1	4	8	23	17.4	4.3	4.4	8.7	8.7	4.3	17.4	34.8
June ...	2	1	2	1	2	3	0	2	13	15.4	7.7	15.4	7.7	15.4	23.1	0.0	15.4
July ...	0	0	0	0	0	0	0	2	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
August ...	0	0	0	0	0	0	0	1	1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
Sept. ...	0	0	0	0	0	0	0	2	2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100.0
October ...	0	1	0	0	0	0	1	1	3	0.0	33.3	0.0	0.0	0.0	0.0	33.3	33.3
Nov. ...	1	1	0	1	1	0	1	4	9	11.1	11.1	0.0	11.1	11.1	0.0	11.1	44.4
Dec. ...	10	6	9	7	5	9	5	19	70	14.3	8.6	12.9	10.0	7.1	12.9	7.1	27.1
Jan. ...	3	7	9	22	14	10	8	23	96	3.1	7.3	9.4	22.9	14.8	10.4	8.3	23.9
Feb. ...	7	13	21	13	8	5	4	28	99	7.1	13.0	21.1	13.0	8.1	5.1	4.0	28.3
March ...	9	19	24	6	12	11	8	33	122	7.4	15.5	19.7	4.9	9.8	9.0	6.6	27.1

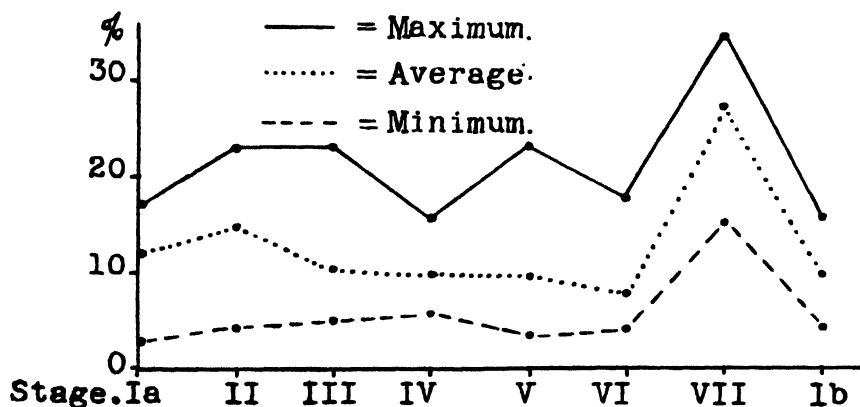


Fig. 10. *C. fatigans*, maximum, minimum and average percentages of abdominal stages for one year (No. 11 catching station).

varies in numbers *pari passu* with the rest of the area ; (iii) thermograph results (p. 576), indicate that the station is a favoured resting place on account of high humidity ; (iv) in spite of the clear proof of ferry steamer importation into Garden Reach at a point close to this station (p. 577), and to a heavy reduction in this effected during the winter of 1933-34 (p. 579), female numbers at No. 11 were not affected.

Table XVIII gives the results of the year's abdominal classification. In graphing the maxima and minima of these the months July to November had to be omitted, owing to the very small numbers involved. The figures for the remaining months are given in fig. 10.

Compared with fig. 8 it will be seen (i) that with the exception of stage II (which has a rather smaller range) every stage has much wider ranges of variation than in the area as a whole; (ii) that there is no outstandingly high percentage of any stage except VII; (iii) that stage VII is in very much higher percentage at No. 11 than in the area generally; (iv) that the direct stage II wet bulb relationship breaks down in March. The only conclusion that can be drawn is that at this station the high female population is composed of a random accumulation of insects in all stages of abdominal development, attracted thereto by meteorological conditions peculiar to the catching station itself. Whatever these conditions are, they are peculiarly attractive to females at full term. It must thus function as a death trap, for though possibly *fatigans*, as Et. Sergeant (1932) has shown for the closely related *pipiens*, can delay oviposition if water is not present, this procedure cannot continue indefinitely. I have often wished to expose suitable water in this station to count egg-rafts, as against similar water exposed in some station where the stage VII percentage is lower, but the experiment, if successful, would release at a very important spot in the control area, a corresponding number of once-again hungry females, thus I have not felt justified in making it.

In conclusion I have to thank my Assistant, Dr. A. K. Adhikari, for carrying on routine counts and classifications during my frequent absences on tour. To Lt.-Col. R. Knowles, I.M.S., of the Calcutta School of Tropical Medicine, and Lt.-Col. J. Sinton, V.C., I.M.S., of the Malaria Survey of India, my thanks are due for the loans of the recording thermographs with which the records referred to on p. 576 were made; and to Mr. Woodhouse, of the Mathematical Instrument Office of the Survey of India, I am equally indebted for rating the same before and after the experiment, for without his help correction factors could not have been applied enabling the crude records of these always unsatisfactory instruments to be made use of. But above all, my thanks are due to my Laboratory Assistant, Babu M. Lazarus. The work carried out by him at all hours of the night has alone enabled many of the data used in Part II to be obtained, and in fact, without his ever-ready willingness to make special investigations, however much labour they caused to himself, much of this paper could not have been written.

3. Summary and Conclusions.

1. Forty-six species of the family CULICIDAE are now known to occur in the City of Calcutta. Notes on the bionomics of forty-four of these are given. About 97 per cent. of the total catch is made up of nine species only. *Culex fatigans* outnumbers all other species manifold.

2. *Stegomyia fasciata* appears to have gradually replaced *S. albopicta* in Calcutta during the present century.

3. The effects of height, and curtains and other hangings, in mosquito incidence in buildings are discussed. *Stegomyia* numbers are not affected by increased elevation.

4. A résumé of the published literature on *C. fatigans* from 1919 to date is given. In spite of its volume a study of it reveals very numerous lacunae. Chemical and bacteriological analyses of a sullage outfall from its source is the chief requirement for the further elucidation of breeding requirements.

5. The number of female *C. fatigans* in a room appears to be influenced by the relative humidity at dawn.

6. *C. fatigans* is very easily transported mechanically. Experiments in proof of this are described. Male flight is shown to be much longer than female. It is most on the move in the first two hours of darkness.

7. Studies on the digestive-ovarian conditions of captured *C. fatigans* show :— (i) that in the month of greatest nuisance, females that have oviposited and are ready to feed again are relatively most numerous ; (ii) that a minimum of $4\frac{1}{2}$ days is required from emergence to oviposition ; (iii) the percentage captured in each stage in an uncontrolled area appears to follow the exponential catenary curve, only about one-eighth of the *fatigans* population of a house being in a state to bite ; (iv) the species is on the move in all stages of abdominal condition, ingress and egress in a house being equal ; (v) the percentage captured in each stage in a controlled area differs greatly from that in an uncontrolled area in respect of unfed and newly fed specimens, but is very similar to it in respect of the later stages, there being a very big reduction in numbers in the latter that does not occur naturally ; (vi) the value of abdominal classification in respect of efficiency of control work is shown ; (vii) there is a direct relationship between percentage of newly fed specimens and wet bulb temperature during the months when the species is increasing in numbers, which falls during the months when these are on the decline.

8. Further studies are necessary in an uncontrolled area, with greater ranges of climate than Calcutta, for any further advance in knowledge of *C. fatigans* bionomics.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st July and 30th September, 1934.

Mr. E. BALLARD, Government Entomologist :—30 Parasitic Hymenoptera ; from Palestine.

Dr. H. F. BARNES, Rothamsted Experimental Station :—180 Parasitic Hymenoptera ; from England.

Dr. MAX BEIER :—41 Parasitic Hymenoptera and 25 other Hymenoptera ; from Greece.

Mr. E. J. H. BERWICK :—2 Parasitic Hymenoptera ; from England.

Mr. P. BORG :—17 Coleoptera ; from Malta.

Mr. H. E. BOX :—4 species of Coccidae ; from Montserrat, British West Indies.

Mr. H. J. BRÉDO :—1,470 Orthoptera ; from the Belgian Congo.

Mr. S. C. BRUNER :—38 Curculionidae ; from Cuba.

Dr. P. A. BUXTON, London School of Tropical Medicine :—188 Culicidae, 57 Tabanidae, 100 *Simulium*, 5 *Stomoxys*, 27 other Diptera, 5 Coleoptera, 2 Hymenoptera, 9 Lepidoptera, 7 Rhynchota, and 10 Orthoptera ; from various localities.

CHIEF ENTOMOLOGIST, PRETORIA :—6 species of Coccidae ; from South Africa.

Mr. A. F. CLARK :—40 Diptera and 40 early stages ; from New Zealand.

Mr. G. H. CORBETT, Government Entomologist :—56 Diptera, 50 Coleoptera, 78 Parasitic Hymenoptera, 150 other Hymenoptera, 11 Lepidoptera, and 40 Isoptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—750 Coleoptera ; from East Africa.

Mr. G. S. COTTERELL, Government Entomologist :—1 species of Aleurodidae ; from the Gold Coast.

Mr. A. CUTHBERTSON, Assistant Entomologist :—6 Diptera ; from Southern Rhodesia.

Dr. J. DAVIDSON, Waite Agricultural Research Institute :—3 Curculionidae ; from South Australia.

Mr. L. DECOUX :—3 Diptera and 9 Parasitic Hymenoptera ; from Belgium.

Dr. H. J. DE FLUITER :—15 Parasitic Hymenoptera and 12 cocoons ; from Holland.

Mrs. V. DICKSON :—2 Orthoptera ; from the Persian Gulf.

Mr. V. H. W. DOWSON :—6 Parasitic Hymenoptera, 10 Lepidoptera, and 1 species of Coccidae ; from Iraq.

Mr. J. L. FROGATT, Government Entomologist :—9 Culicidae, 38 other Diptera, 105 Coleoptera, 38 Parasitic Hymenoptera, 22 other Hymenoptera, 31 Lepidoptera, 2 species of Coccidae, 51 Rhynchota, 8 Orthoptera, and 2 Dermaptera ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—53 Tachinidae ; from the United Provinces, India.

Mr. S. GARTHSIDE :—4 Diptera, 4 Coleoptera, 41 Parasitic Hymenoptera, 3 Lepidoptera, 7 Rhynchota, 7 Planipennia, and 1 species of Eriophyidae ; from England ; and 13 Coleoptera ; from Australia.

Mr. C. C. GHOSH :—100 Coleoptera, 31 Lepidoptera, and 2 species of Aphidae ; from Burma.

Mr. F. D. GOLDING, Government Entomologist :—15 Coleoptera and 192 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, KAMPALA :—2 Tabanidae, 12 other Diptera, 67 Coleoptera, 7 Parasitic Hymenoptera and 2 cocoons, 16 other Hymenoptera, 298 Lepidoptera, 61 Rhynchota, 3 Orthoptera, and 2 Planipennia ; from Uganda.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—100 Parasitic Hymenoptera and 500 other Hymenoptera ; from the Punjab, India.

Mr. A. M. GWYNN, Assistant Entomologist :—5 Diptera, 8 Parasitic Hymenoptera, 39 Formicidae, 3 species of Coccidae, and 150 Collembola ; from Nigeria.

Mr. G. L. R. HANCOCK, Assistant Entomologist :—3 species of Aleurodidae ; from Uganda.

Mr. E. HARGREAVES, Government Entomologist :—27 *Stomoxys*, 94 other Diptera, 72 Coleoptera, 135 Parasitic Hymenoptera, 9 other Hymenoptera, 96 Lepidoptera, 20 Isoptera, 200 Thysanoptera, 33 Rhynchota, 20 Orthoptera, 2 Dermaptera, 3 Planipennia, 2 Trichoptera, and 3 Spiders ; from Sierra Leone.

Mr. W. V. HARRIS, Assistant Entomologist :—26 Diptera, 50 Coleoptera, 150 Parasitic Hymenoptera, 6 Lepidoptera, 30 Thysanoptera, 1 species of Psyllidae, and 92 other Rhynchota ; from Tanganyika Territory.

Dr. OTTO HECHT :—80 Parasitic Hymenoptera ; from Palestine.

Mr. H. J. HOCKINGS :—4 Nycteribiidae, 12 other Diptera and 5 pupa cases, 41 Coleoptera, 700 Parasitic Hymenoptera, 4 Formicidae, 43 Lepidoptera, 20 Isoptera, 4 Rhynchota, and 4 Crustacea ; from Queensland.

Mr. W. E. H. HODSON :—6 Parasitic Hymenoptera and 2 Blattidae ; from England.

Dr. W. HORN :—2,045 Coleoptera ; from various localities.

Mr. G. V. HUDSON :—7 Diptera and 54 Coleoptera ; from New Zealand.

IMPERIAL ENTOMOLOGIST, PUSA :—2 Coleoptera, 11 Parasitic Hymenoptera, 12 Lepidoptera, 12 species of Aphidae, 25 species of Coccidae, and 9 other Rhynchota ; from India.

INDIAN LAC RESEARCH INSTITUTE :—31 Parasitic Hymenoptera ; from Bihar, India.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—109 Lepidoptera ; from the Dutch East Indies.

Miss D. J. JACKSON :—7 Parasitic Hymenoptera ; from Scotland.

Mr. H. B. JOHNSTON :—13 Orthoptera ; from Uganda.

Mr. R. T. JONES :—5 Diptera and 20 early stages ; from England.

Dr. K. R. KARANDIKAR :—2 Hippoboscidae, 9 other Diptera, 5 Coleoptera, 2 Parasitic Hymenoptera, and 12 other Hymenoptera ; from Baluchistan.

Mr. L. A. L. KING :—6 Parasitic Hymenoptera and 6 cocoons ; from Scotland.

Dr. R. H. LE PELLEY, Assistant Entomologist :—58 Rhynchota ; from Kenya Colony.

Prof. F. J. MEGGITT :—15 Tabanidae, 42 other Diptera and 300 larvae, 945 Coleoptera and 110 early stages, 5 Parasitic Hymenoptera, 188 other Hymenoptera, 8 Lepidoptera and 25 early stages, 250 Isoptera, 2 species of Coccidae, 1 species of Aleurodidae, 3 Cicadid exuviae, 405 other Rhynchota, 113 Orthoptera, 2 Planipennia, and 7 Marine Worms ; from Burma.

Mr. E. MEYRICK, F.R.S. :—100 Lepidopterous larvae ; from England.

Mr. J. MUGGERIDGE, Government Entomologist :—14 Diptera, 13 Coleoptera, 78 Parasitic Hymenoptera, and 35 Rhynchota ; from New Zealand.

Mr. H. K. MUNRO :—2 Diptera ; from South Africa.

MUSÉE DU CONGO BELGE, TERVUEREN :—10 Diptera, 15 Parasitic Hymenoptera, and 7 species of Coccidae ; from the Belgian Congo.

Dr. J. G. MYERS :—28 Coleoptera and 100 Parasitic Hymenoptera ; from Trinidad.

Dr. T. A. M. NASH :—11 Diptera and 204 larvae ; from Northern Nigeria.

Messrs. G. NELSON, DALE & Co., Ltd. :—30 Anobiidae ; from England.

Messrs. H. T. PAGDEN & R. A. LEVER, Government Entomologists :—5 Culicidae, 4 Tabanidae, 337 other Diptera, 375 Coleoptera, 534 Parasitic Hymenoptera and 30 cocoons, 58 other Hymenoptera, 35 Lepidoptera, 2 species of Coccidae, 1 species of Aphidae, 252 other Rhynchota, 2 Orthoptera, 36 Mallophaga, 30 Parasitic Worms, and 6 Birds ; from the Solomon Islands.

Mr. Y. RAMACHANDRA RAO :—41 Diptera, 327 Coleoptera, 49 Hymenoptera, 49 Lepidoptera, 43 Rhynchota, 315 Orthoptera, 2 Embiidæ, 12 Planipennia, 4 Odonata, 2 Ephemæridæ, and 2 Mites ; from Baluchistan.

Mr. S. ANANDA RAU :—10 Diptera, 21 Coleoptera, 45 Parasitic Hymenoptera, 15 Lepidoptera, 20 Thysanoptera, 9 Rhynchota, and 4 Orthoptera ; from South India.

Mr. A. H. RITCHIE, Government Entomologist :—11 Curculionidæ ; from Tanganyika Territory.

Dr. E. RIVNAY :—2 Hippoboscidæ, 43 other Diptera, 186 Coleoptera, 8 Parasitic Hymenoptera, 15 other Hymenoptera, 55 Lepidoptera, 26 Rhynchota, 2 Dermaptera, and 6 Planipennia ; from Palestine.

Mr. K. ROOS :—2 Diptera and 3 Parasitic Hymenoptera ; from Switzerland.

ROYAL BOTANIC GARDENS KEW :—1 Beetle ; from French Guinea.

Dr. HANS SACHTLEBEN :—7 Parasitic Hymenoptera ; from Bulgaria.

SELANGOR MUSEUM :—136 Coleoptera ; from the Straits Settlements.

SEYCHELLES COMPANY :—1 species of Coccidæ ; from the Seychelles.

Mr. H. W. SIMMONDS, Government Entomologist :—7 Diptera, 6 Coleoptera, 14 Lepidoptera, 1 species of Coccidæ, and 4 other Rhynchota ; from Fiji.

Mr. H. D. SMITH :—76 Parasitic Hymenoptera ; from France.

Dr. H. H. STOREY, Plant Pathologist :—2 species of Aleurodidæ ; from Tanganyika Territory.

Prof. J. STROHL :—13 Parasitic Hymenoptera ; from Switzerland.

Mr. J. SUIRE :—4 Parasitic Hymenoptera ; from France.

Mr. C. B. SYMES, Medical Entomologist :—3,000 *Glossina* ; from Kenya Colony.

Mr. T. H. C. TAYLOR :—70 Parasitic Hymenoptera, 100 other Hymenoptera, and 50 Mites ; from Fiji and Java.

Mr. W. THOMSON :—1 Culicid ; from the Gold Coast.

Dr. A. L. TONNOIR :—1 species of Aleurodidæ ; from Australia.

Mr. R. VEITCH, Chief Entomologist :—3 Diptera, 48 Coleoptera, and 4 Parasitic Hymenoptera ; from Queensland.

Dr. F. ZACHER :—2 Coleoptera and 4 Lepidoptera ; from Germany.

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COLLECTIONS RECEIVED.

The following collections were received by the Imperial Institute of Entomology between 1st April and 30th June, 1934.

AGRICULTURAL OFFICER, QUETTA :—4 Diptera, 29 Coleoptera, 8 Hymenoptera, 11 Lepidoptera, and 2 Planipennia ; from Baluchistan.

Mr. T. J. ANDERSON, Government Entomologist :—200 Isoptera ; from Kenya Colony.

ANGLO-CONTINENTAL GUANO WORKS, LONDON :—1 species of Aphidae and 20 Gryllidae ; from Syria.

Dr. H. F. BARNES, Rothamsted Experimental Station :—2 Orthoptera ; from England.

Dr. M. BENSAUDE :—1 species of Coccidae ; from Portugal.

Dr. H. BLÜNCK :—10 Parasitic Hymenoptera ; from Germany.

Dr. F. S. BODENHEIMER :—250 Collembola ; from Palestine.

Mr. P. BORG :—12 Coleoptera and 4 early stages ; from Malta.

Mr. H. BRITTON :—48 Braconidae ; from England.

Dr. K. S. F. CHANG :—45 Orthoptera ; from China.

CHIEF ENTOMOLOGIST, PRETORIA :—3 Coleoptera and 24 Rhynchota ; from South Africa.

Mr. S. F. CHIU :—7 Orthoptera ; from China

Mr. G. H. CORBETT, Government Entomologist :—5 Diptera, 9 Coleoptera, 57 Parasitic Hymenoptera, 63 other Hymenoptera, 64 Lepidoptera, 400 Isoptera, 6 Rhynchota, and 2 Orthoptera ; from Malaya.

CORYNDON MEMORIAL MUSEUM, NAIROBI :—653 Coleoptera ; from East Africa.

Mr. R. C. M. DARLING :—172 Orthoptera ; from the Sudan.

Mr. M. DELASSUS :—30 Parasitic Hymenoptera ; from Algeria.

Mrs. V. DICKSON :—6 Coleoptera, 2 Rhynchota, 28 Orthoptera, and 2 Spiders ; from the Persian Gulf.

DIRECTOR OF AGRICULTURE, SEYCHELLES :—1 species of Coccidae ; from the Seychelles.

DIRECTOR OF PUBLIC WORKS, LAGOS :—50 Isoptera ; from Nigeria.

Mr. A. P. DODD :—100 Parasitic Hymenoptera ; from Queensland.

Mr. V. H. W. DOWSON :—17 Coleoptera, 14 Lepidoptera and 8 larvae, and 10 Mites ; from Iraq.

EAST AFRICAN AGRICULTURAL RESEARCH STATION, AMANI :—8 Gryllidae ; from Zanzibar.

Mr. H. J. de FLUITER :—9 Parasitic Hymenoptera ; from Holland.

Mr. S. B. FREEBORN :—9 slides of Diptera ; from California.

Mr. J. L. FROGGATT, Government Entomologist :—160 Diptera, 52 Coleoptera, 37 Parasitic Hymenoptera, 17 other Hymenoptera, 12 Lepidoptera, 1 species of Aleurodidae, 12 other Rhynchota, 2 Orthoptera, and 2 Chrysopidae ; from New Guinea.

Mr. J. C. M. GARDNER, Systematic Entomologist :—61 Diptera, 75 Curculionidae, 48 Parasitic Hymenoptera and 7 cocoons ; from the United Provinces, India.

Mr. S. GARTHSIDE :—5 Diptera and 3 pupae, 10 Coleoptera, 15 Parasitic Hymenoptera and 8 cocoons, 2 Rhynchota, and 21 Planipennia ; from England and France.

Mr. F. D. GOLDING, Government Entomologist :—2 Hymenoptera, 6 Lepidoptera, and 29 Orthoptera ; from Nigeria.

GOVERNMENT ENTOMOLOGIST, LYALLPUR :—9 Diptera, 260 Coleoptera, 39 Parasitic Hymenoptera, 31 Lepidoptera, and 2,000 Mites ; from the Punjab, India.

Mr. A. M. GWYNN, Assistant Entomologist :—50 Parasitic Hymenoptera and 50 cocoons, and 138 Orthoptera ; from Nigeria.

Mr. E. HARGREAVES, Government Entomologist :—72 Diptera, 46 Coleoptera, 80 Parasitic Hymenoptera, 5 other Hymenoptera, 137 Lepidoptera, 10 Isoptera, 230 Thysanoptera, 5 species of Coccidae, 1 species of Aphidae, 28 other Rhynchota, 4 Orthoptera, 2 Planipennia, 2 Ephemeridae, and 21 Trichoptera ; from Sierra Leone.

Mr. W. V. HARRIS, Assistant Entomologist :—40 Coleoptera ; from Tanganyika Territory.

Mr. G. L. HEY :—10 Parasitic Hymenoptera and 2 cocoons ; from England.

Mr. G. H. E. HOPKINS, Entomologist :—121 Hippoboscidae ; from Uganda.

IMPERIAL ENTOMOLOGIST, PUSA :—300 Isoptera and 13 Orthoptera ; from India.

INSTITUTE FOR PLANT DISEASES, BUITENZORG :—64 Coleoptera, 77 Lepidoptera, and 18 Rhynchota : from the Dutch East Indies.

Mr. H. B. JOHNSTON :—79 Orthoptera ; from Uganda.

Mr. G. L. JONES :—1 Moth and 1 Blattid ; from England.

Mr. C. B. R. KING :—16 Parasitic Hymenoptera ; from Ceylon.

Mr. H. Z. KLEIN :—1,000 Mites ; from Palestine.

Mr. W. R. S. LADELL :—185 Diptera, 101 Coleoptera, 14 Parasitic Hymenoptera, 93 other Hymenoptera, 6 Lepidoptera, 93 Rhynchota, 7 Orthoptera, and 14 Crustacea ; from Siam.

Dr. LI. LLOYD :—19 Tabanidae, 140 other Diptera, 2,165 Coleoptera, 283 Hymenoptera, 722 Lepidoptera, 10 Isoptera, 780 Rhynchota, 1,049 Orthoptera, 20 Dermaptera, 53 Planipennia, 214 Odonata, and 5 Shells ; from Northern Nigeria : 4 Diptera, 33 Coleoptera, 48 Hymenoptera, and 17 Rhynchota ; from Borneo : and 29 Diptera, 795 Coleoptera, 12 Hymenoptera, 61 Lepidoptera, 148 Rhynchota, 2 Orthoptera, and 50 Odonata ; from Northern Rhodesia.

Prof. F. J. MEGGITT :—4 Coleoptera ; from Burma.

Dr. B. De MEILLON :—11 Curculionidae ; from South Africa.

Mr. J. E. M. MELLOR :—69 Parasitic Hymenoptera ; from England.

Messrs. MILNE & Co. :—3 Coleoptera and 3 larvae ; from Burma.

Mr. L. MORISON :—6 Cecidomyiidae, 13 Coleoptera and 8 larvae, 5 Parasitic Hymenoptera, 5 Lepidoptera and 6 larvae, and 6 Ticks ; from New Zealand.

Mr. M. C. MOSSOP, Assistant Entomologist :—21 Coleoptera, 60 Parasitic Hymenoptera, 9 Rhynchota, and 10 Mites ; from Southern Rhodesia.

Mr. A. MOUTIA, Assistant Entomologist :—3 Diptera and 20 Isoptera ; from Mauritius.

Mr. R. W. MUNGOMERY :—9 Coleoptera ; from Queensland.

MUSEUM NATIONAL D'HISTOIRE NATURELLE, PARIS :—105 Curculionidae ; from various localities.

Dr. J. G. MYERS :—2 Diptera and 3 larvae, 320 Parasitic Hymenoptera, 53 other Hymenoptera, 5 Lepidoptera, 20 Thysanoptera, 9 species of Coccidae, 20 Psyllidae, 6 Orthoptera, and 2 Millipedes ; from Tropical America.

Prof. R. NEWSTEAD, F.R.S.—6 Curculionidae ; from England.

Messrs. H. T. PAGDEN and R. A. LEVER :—Government Entomologists :—9 Culicidae, 2 Tabanidae, 191 other Diptera, 391 Coleoptera, 271 Parasitic Hymenoptera, 101 other Hymenoptera, 170 Lepidoptera, 430 Isoptera, 362 Rhynchota, 225 Orthoptera, 10 Dermaptera, 2 Embiidae, 4 Planipennia, 9 Odonata, 10 Mallophaga, 18 Anoplura, 3 Chelifera, 4 Millipedes, 15 Crustacea, and 20 Mollusca ; from the Solomon Islands.

Mr. R. W. PAINE :—10 Diptera and 5 pupa-cases, 12 Parasitic Hymenoptera and 2 cocoons, and 15 Lepidoptera ; from Fiji.

Mr. J. PALMONI :—2 Tabanidae, 29 other Diptera, 29 Coleoptera, 271 Hymenoptera, 15 Lepidoptera and 3 larvae, 1 species of Aphidae, 16 other Rhynchota, 17 Orthoptera, 12 Odonata, 4 Ephemeridae, 6 Trichoptera, and 3 Spiders ; from Palestine.

Mr. D. B. PICKEL :—10 Curculionidae ; from Brazil.

Dr. S. V. PILL :—150 Orthoptera ; from South Persia.

Mr. J. de B. R. QUEIROZ :—5 Parasitic Hymenoptera ; from Angola.

Mr. S. A. RAU :—5 Coleoptera, 10 Lepidoptera, and 12 Thysanoptera ; from South India.

Dr. P. REGNIER :—47 Orthoptera ; from French Morocco.

Dr. W. E. RIPPER :—14 Parasitic Hymenoptera ; from Austria.

Mr. A. H. RITCHIE, Government Entomologist :—4 Melolonthidae ; from Tanganyika Territory.

Mr. D. R. ROSEVEAR :—2 Culicidae, 4 Tabanidae, 3 *Glossina*, 36 other Diptera, 307 Coleoptera, 14 Parasitic Hymenoptera, and 10 cocoons, 47 other Hymenoptera, 2 Isoptera, 134 Rhynchota, 12 Orthoptera, 5 Dermaptera, 7 Planipennia and 2 early stages, 9 Odonata, 10 Ephemeridae and 6 egg-masses, and 12 Trichoptera ; from Nigeria and the Cameroons.

Messrs. A. SANDERSON & SONS :—6 Thysanura ; from England.

Mr. NIHAT SCHEWKET :—70 Coleoptera and 37 Rhynchota ; from Asiatic Turkey.

Mr. A. F. DE SEABRA :—137 Orthoptera ; from various localities.

Mr. L. F. DE SEQUEIRA :—14 Culicidae and 4 larvae, 31 other Diptera, 8 Ticks and 10 Mites ; from Portuguese Guinea.

Mr. H. W. SIMMONDS, Government Entomologist :—3 Diptera, 8 Coleoptera, 2 Parasitic Hymenoptera, 14 Lepidoptera, 1 species of Coccidae, 2 species of Aphidae, and a tube of Mites ; from Fiji.

Prof. C. STRICKLAND :—3 Hymenoptera and 2 early stages and 3 Rhynchota ; from India.

Mr. F. A. SQUIRE, Government Entomologist :—6 Tabanidae, 49 other Diptera, 23 Coleoptera and 8 early stages, 28 Parasitic Hymenoptera, 70 other Hymenoptera, 7 Lepidoptera, 70 Isoptera, 100 Thysanoptera, 1 species of Coccidae, 3 species of Aphidae, 4 other Rhynchota, 4 Orthoptera, 20 Mallophaga, 50 Mites, 8 Millipedes, and 4 Slugs ; from British Guiana.

Mr. T. V. SUBRAMANIAM, Entomologist :—5 Diptera and 2 pupa-cases, 7 Coleoptera, 7 Parasitic Hymenoptera, 34 tubes and 56 slides of Coccidae ; from Mysore, India.

Dr. F. SUTHERLAND :—1 Melolonthid ; from England.

Mr. J. S. TAYLOR :—176 Coleoptera, 100 Parasitic Hymenoptera, 5 other Hymenoptera, 3 Lepidoptera, 72 Rhynchota, and 14 Hemerobiidae ; from South Africa.

Dr. P. VAYSSIÈRE :—29 Parasitic Hymenoptera.

Mr. C. WATANABE :—113 Parasitic Hymenoptera and 200 cocoons ; from Japan.

WELLCOME TROPICAL RESEARCH LABORATORIES, KHARTOUM :—5 Tabanidae, 102 other Diptera, 205 Coleoptera, 100 Parasitic Hymenoptera, 178 Rhynchota, a tube of Mites, and 30 Spiders ; from the Sudan.

Mr. W. E. WHITEHEAD :—60 Mallophaga ; from Canada.

Mr. G. FOX WILSON :—13 Parasitic Hymenoptera ; from England.

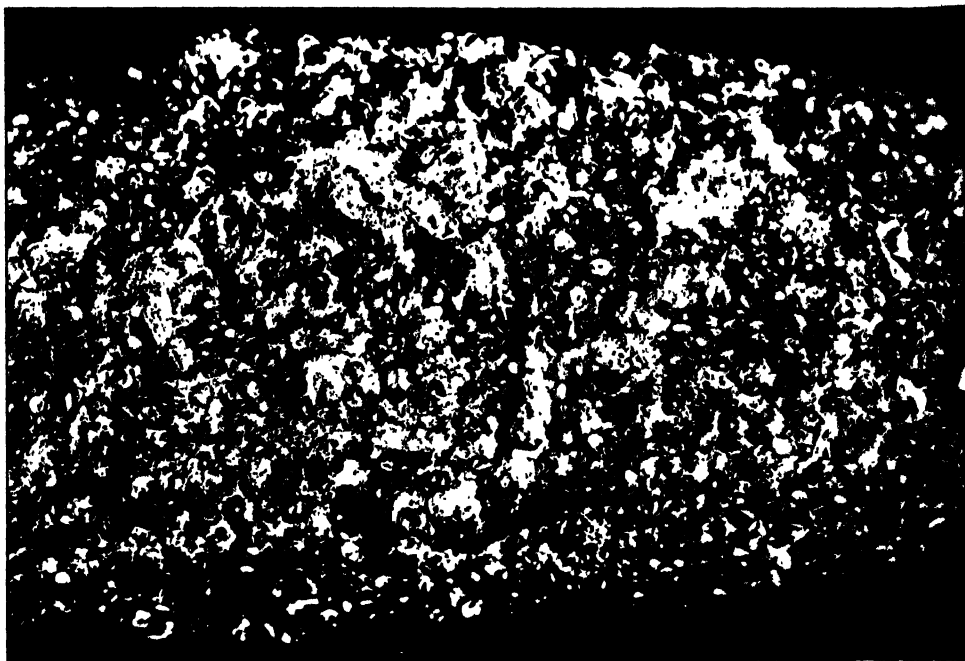


Fig 1. Choram grains damaged by *Coreyra cephalonica* showing numerous cocoons and nature of damage.

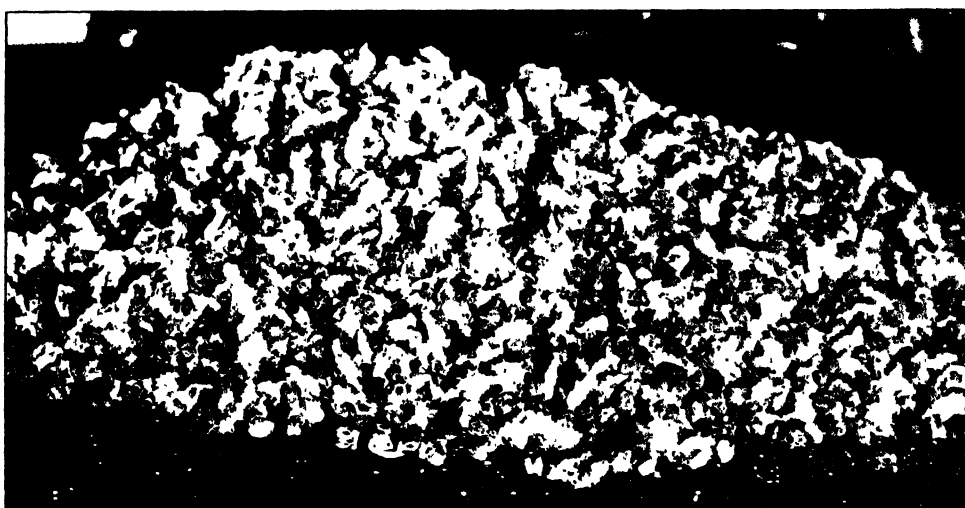


Fig. 2. Stored Bengal gram infested with *C. cephalonica* showing clusters of cocoons (matted together).

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